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CONTROL

SYSTEMS · INSTRUMENTATION · DATA PROCESSING · ENGINEERING · APPLICATIONS

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LOOKING FOR A JOB? Control *carries the best jobs in instrument and control engineering.* **SEE PAGE 162 AND ONWARDS**

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LOOKING AHEAD

Unless otherwise indicated, all events take place in London. B.C.A.C., British Conference on Automation and Computation. B.C.S., British Computer Society. Brit.I.R.E., British Institution of Radio Engineers. I.C.E., Institution of Civil Engineers. I.Chem.E., Institution of Chemical Engineers. I.E.E., Institution of Electrical Engineers. I.Mech.E., Institution of Mechanical Engineers. I.Prod.E., Institution of Production Engineers. I.S.A., Instrument Society of America. R.Ae.S., Royal Aeronautical Society. S.B.A.C., Society of British Aircraft Constructors. S.I.T., Society of Instrument Technology.

SUNDAY 20—WEDNESDAY 23 AUGUST
First International Congress on *Ergonomics*. Stockholm. Details: Dr S. Forssman, Swedish Employers' Confederation, S. Blasieholmshammen 4A, Stockholm 16, Sweden.

World Traffic Engineering Conference. Washington. Organizers: International Road Federation, 1023 Washington Bldg, Washington 5, D.C., U.S.A.

WED. 30 AUGUST—WED. 6 SEPTEMBER
Annual Meeting, British Association for the Advancement of Science. Norwich. Details: Secretary, B.A.A.S., 19 Adam St, Strand, London, W.C.2.

SUNDAY 3—TUESDAY 12 SEPTEMBER
European Machine Tool Exhibition. Brussels. Details: Commissariat Général de la 7e Exposition Europeéne de la Machine-Autil, 13 rue des Drapiers, Bruxelles 5, Belgium; and The Machine Tool Trades Association, Metalworking Machine Tool Manufacturers Section, Brettenham Ho., Lancaster Place, London, W.C.2.

MONDAY 4—FRIDAY 8 SEPTEMBER
Rutherford Jubilee International Conference. Details: L. J. B. Goldfarb, Physics Dept, University of Manchester, Manchester, Lancs.

MONDAY 4—SATURDAY 9 SEPTEMBER
3rd International Session of the International Association for Analogue Computation. Belgrade, Yugoslavia. Details: Yugoslav Committee for Etan, Terazije, 23/VII, Belgrade, Yugoslavia.

MONDAY 4—SUNDAY 10 SEPTEMBER
S.B.A.C. Flying Display and Exhibition. Farnborough. Details: S.B.A.C., 29 King St, St James's, London, S.W.1.

TUESDAY 5—FRIDAY 8 SEPTEMBER
An international conference on *Machine translation of language and applied language analysis*. National Physical Laboratory, Teddington, Middlesex. Papers to Dr A. M. Uttley, Autonomics Div., N.P.L.

National Inspection Conference (jointly with National Committee on Non-destructive Testing). New College, Oxford. Details: Institution of Engineering Inspection, Grand Bldgs, 616 Trafalgar Sq., London, W.C.2.

WEDNESDAY 6—FRIDAY 8 SEPTEMBER
International Symposium on *Transmission and processing of information*. Massachusetts Institute of Technology. Submission of papers is invited. Details: R. M. Fano, R.L.E., M.I.T., Cambridge, 39, Mass., U.S.A.

Joint Nuclear Instrumentation Symposium. North Carolina State College, Raleigh, N.C., U.S.A. Sponsors: I.S.A., A.I.E.E., I.R.E. Details: Meetings Manager, I.S.A., 313 Sixth Av., Pittsburgh, 22, Pa, U.S.A.

MONDAY 11 SEPTEMBER
20th International Congress of Navigation. Baltimore. Details: Permanent International Association of Navigation Congresses, 60 rue Juste Lipse, Brussels, Belgium.

MONDAY 11—WEDNESDAY 13 SEPTEMBER
Fifth International Congress of the European Organization for Quality Control. Turin, Italy. Details: European Organization for Quality Control, Weena 700, Rotterdam, Holland.

MONDAY 11—FRIDAY 15 SEPTEMBER
I.S.A. Instrument-Automation Conference and Exhibition and I.S.A.'s 16th Annual Meeting. Memorial Sports Arena, Los Angeles, Calif., U.S.A. Details: Wm H. Kushnick, I.S.A., 313 Sixth Av., Pittsburgh, 22, Pa, U.S.A.

Third International Congress on *Cybernetics*. Namur, Belgium. Details: Association Internationale de Cybernétique, 13 rue Basse-Marcelle, Namur, Belgium.

MONDAY 18—FRIDAY 22 SEPTEMBER
Symposium on *Network theory*. Cranfield. Details: S.R. Deards, Department of Electrical and Control Engineering, The College of Aeronautics, Cranfield, Bletchley, Bucks.

MONDAY 25—SATURDAY 30 SEPTEMBER
International Conference on *Magnetism and crystallography*. Kyoto, Japan. Details: Organizing Committee, Science Council of Japan, Ueno Park, Tokyo, Japan.

TUESDAY 26 SEPTEMBER—FRIDAY 6 OCTOBER
International Heating, Ventilating and Air-conditioning Exhibition. Olympia. (A conference will run concurrently from Wednesday 27 September — Wednesday 4 October.) Sponsors: Institution of Heating and Ventilating Engineers.

MONDAY 2—WEDNESDAY 11 OCTOBER
Business Efficiency Exhibition, Olympia. Details: Hart-Lidbury, Panton Ho., 25 Haymarket, S.W.1.

WEDNESDAY 4—THURSDAY 12 OCTOBER
Second Electronic Computer Exhibition and Symposium, London. Details: Mrs S. S. Elliott, 64 Cannon St, E.C.4.

THURSDAY 5—FRIDAY 6 OCTOBER
Two-day export conference. Details: C. G. E. Parrot, Overseas Div., B.E.A.M.A., 36 Kingsway, W.C.2.

THURSDAY 19 OCTOBER
The Thomson Lecture: *The inspiration of science*, by Sir George Thomson at 6 p.m. at The Royal Institution. Admission by ticket only. (*S.I.T.*)

TUESDAY 24—THURSDAY 26 OCTOBER
National Conference of the British Institute of Management. Details: Miss E. Ellett, 80 Fetter Lane, E.C.4.

TUESDAY 31 OCTOBER—FRIDAY 3 NOVEMBER
Effluent and Water Treatment Exhibition and Convention. Seymour Hall. Details: P. I. Craddock, Dale Reynolds Publicity, 2 Broad Street Place, E.C.2.

WEDNESDAY 8—FRIDAY 10 NOVEMBER
Conference on *Non-destructive testing in electrical engineering*. (*I.E.E.*)

MONDAY 13—SATURDAY 18 NOVEMBER
Second Engineering Materials and Design Exhibition and Conference. Earls Court. Details: J. Brewster, Commonwealth Ho., New Oxford St, W.C.1.

International Factory Equipment Exhibition. Earls Court. Details: J. Brewster, Commonwealth Ho., New Oxford St, W.C.1.

FRIDAY 17—SATURDAY 18 NOVEMBER
Conference on *Imperfections in crystals*. Institution of Mechanical Engineers, London. Details: The Administrative Assistant, The Institute of Physics and The Physical Society, 47 Belgrave Sq., S.W.1.

LOOKING FURTHER AHEAD

WEDNESDAY 17—THURSDAY 18 JANUARY 1962
A symposium on *Electronic aids to banking*, under the aegis of B.C.A.C. Details: I.E.E.

MONDAY 22 JANUARY 1962
'Exposition meeting' on *Recent developments in automatic boiler control practice*. Details: R. J. Redding, 66 The Drive, Isleworth, Mddx. (*See also Control, July, p.* 122). (*S.I.T.*)

FRIDAY 16—TUESDAY 20 FEBRUARY 1962
Salon Internationale des Composants Electroniques. Parc des Expositions, Porte de Versailles. Details: S.D.S.A., 23 rue de Lubeck, Paris 16e, France.

APRIL 1962
'Exposition meeting' on *Self adaptive control systems*. Details and suggestions: R. H. Tizard, Whitterick, Ellesmere Rd, Weybridge, Surrey (*See also Control, July, p.* 122). (*S.I.T.*)

WEDNESDAY 25 APRIL—FRIDAY 4 MAY 1962
Conference Internationale des Arts Chimique. Paris. Details: Maison de la Chimique, 28 bis rue Saint-Dominique, Paris 7e, France.

MONDAY 30 APRIL—FRIDAY 4 MAY 1962
Second International Compressed Air and Hydraulics Exhibition. Olympia. Details: W. G. H. Chesher, St Richard's Ho., Eversholt St, N.W.1.

TUESDAY 8—FRIDAY 18 MAY 1962
Mechanical Handling Exhibition. Earls Court. Details: H. A. Collman, Dorset Ho., Stamford St, S.E.1.

THURSDAY 31 MAY—THURSDAY 7 JUNE 1962
International Television Conference. Institution building, London. (*I.E.E.*).

WEDNESDAY 20—TUESDAY 26 JUNE 1962
Third Congress of the European Federation of Chemical Engineering. Olympia. Details: The General Secretary, Society of Chemical Industry, 14 Belgrave Sq., S.W.1.

MONDAY 16—FRIDAY 20 JULY, 1962
International conference on *The physics of semiconductors*. Exeter University. Details: The Administrative Assistant, The Institute of Physics and The Physical Society, 47 Belgrave Sq., London, S.W.1.

TUESDAY 14—THURSDAY 16 AUGUST 1962
Conference on *Standards and electronic measurements*. Boulder Laboratories of the National Bureau of Standards. Details: J. M. Richardson, Radio Standards Laboratory, National Bureau of Standards, Boulder, Colo., U.S.A.

THURSDAY 15—TUESDAY 20 OCTOBER 1962
International Congress and Exhibition of Laboratory, Measurement and Automation Techniques in Chemistry (Ilmac). Swiss Industries Fair, Basle, Switzerland. Details: M. Trottmann, Foire Suisse, d'Echantillons Basle, Switzerland.

SEPTEMBER 1963
Second congress of the International Federation of Automatic Control. (Ifac). Basle, Switzerland. Details: papers, B.C.A.C., c/o I.E.E.; general inquiries, Dr-Ing. G. Ruppel, Prinz-Georg-Strasse 79, Düsseldorf, Germany.

AUGUST 1961 VOL. 4 No. 38 CONTROL

Three problems of automation

THE MINISTER FOR SCIENCE has put the matter into a frightening perspective by saying that, *one day*, extended experience may give the nation an elaborate insight into the essential characteristics of automation. The Minister said this when speaking at the opening of the B.C.A.C.'s Conference on the Social and Economic Effects of Automation. The assembled conferers mostly skated round the subject in their subsequent deliberations, expressing hopes and fears, with emphasis too often on the fears. Trade union representatives were present in force, full of misgivings over the hardships that might arise during a clumsily managed transition; but they spoke very reasonably, and there was so much agreement between them and the managerial speakers that an innocent observer might have wondered how such sensible folk could ever disagree.

Science and technology were taken for granted at this conference. It was assumed that the efforts of engineers would blossom and means of automation would evolve. Thus automation was virtually taken to be the independent variable and society the dependent variable. On this sort of basis the economic problems of automation were labelled by one speaker (J. A. C. Brown, Cambridge) under three categories, which he discussed in turn: investment in plant, adaptation of labour, and forecasting to guide both investment and labour. The aptness of this division revealed itself repeatedly during the conference.

With regard to the first category of problem, Brown himself made one of the more telling points when he quoted authority for believing that British investment in manufacturing industry was bigger in 1948–56 than the corresponding west German investment. This statistic seems to contradict the popular gloss that the Germans, having rebuilt from scratch after the war, are forging ahead because they have put in more new equipment.

Some of the other speakers devoted themselves more particularly to the labour problem. Among them Hugh Clegg (Oxford) claimed, as did a number of trade union leaders later, that while automation reduces the need for manual exertion, it also increases the demand for intelligence and knowledge because the 'worker' now has to supervise the automatic controls. Clegg thought that this would weaken the case for paying production workers by results, and a trade union speaker (J. L. Jones, Transport and General Workers) gave examples to confirm his own view that incentive schemes are out of place in automatized factories. This kind of discussion led inevitably to questions of motivation. What will automation do for people, and how will they choose to use the benefits? Clegg said that he expected most of the gain to be taken in raising the standard of living, with reduction in working hours following slowly behind. Certainly that has been the trend so far, and complex pay systems have evolved as a reflexion of it. Jones argued cogently for a new and simplified wages structure, and his case attracted notice in the daily press.

Another union man who caught the public eye during the conference was W. J. Carron (Amalgamated Engineering Union), who seemed to be more sold on automation than are many British employers. But then, he had had the advantage of a 'visit to a fully automated establishment, controlled electronically, with feedback and electronic brain', and he had felt the impact of this to be 'massive', 'indescribable', 'and a splendid and completely acceptable triumph of mankind'. Perhaps more British industrialists should follow in Carron's footsteps—the plant that so impressed him is in the U.S.S.R.

Brown's third problem, forecasting and guidance, was a recurring theme at the conference. It came up in one of its guises during the discussion of Carron's paper, when L. Landon Goodman (Electrical Development Association) suggested the formation of a National Department of Automation. Carron told us later that he was not sure about this one, and that he would prefer to think it over. Sir Walter Puckey, Chairman of the B.C.A.C., was also doubtful about the idea.

We respect these gentlemen for their caution, since we ourselves dread excessive envelopment of the national effort by officialdom, but unless industry and the engineering profession can do greater things than hitherto by spontaneous combination, another government department or ministry may yet be the best solution. There is a good case for setting up an authority to help coordinate scientific, industrial and social work on automation. To say that 'one day' the nation will be able to look back and view what it has done is not enough.

G. M. E. Williams of Northampton C.A.T. gives his view of the conference in an article on p. 68 ff of this issue.

LETTERS to the EDITOR

Help!

SIR: Dr. Westcott's article on adaptive control* is written so racily that I was carried along by its easy style under an illusion of understanding it all! In fact, however, my education did not include the sort of calculus that he talks about, and the statistics I have picked up seem to be on a much more primitive level than Dr. Westcott's. Could you persuade this gifted contributor of yours to provide a short bibliography that would help a 1950 graduate to bridge the gap?

Cardiff RONALD WHITE

● *Dr Westcott writes: 'Mr White's request is most welcome. A good book for introduction to statistics of random processes is "Random processes in automatic control" by J. H. Laning and R. H. Battin: McGraw Hill, 1956. For the more specific question of Markoff processes an interesting little book is "Markoff processes and dynamic programming" by R. Howard: Technology Press, 1960. Time series analysis is dealt with very fully in "Measurement of Power Spectra from the Point of View of Communication Engineering" by Tukey and Blackman: Dover Publications, 1960. This last reference is rather difficult, but is particularly recommended as giving the communication engineer's point of view of questions of statistical estimation.*

'The next major subject is the question of variational calculus. An elementary introduction is given in "Mathematics for Engineers and Physicists" by L. A. Pipes: McGraw Hill, 1946. A very complete treatment of the classical theory is given in "The Variational Principles of Mechanics" by Cornelius Lanczos: University of Toronto Press, 1949.

'Finally we come to dynamic programming, a modern variant of variational calculus. The prime reference here is "Dynamic programming" by Richard Bellman: Oxford University Press, 1959. Very recently there has been a further book which is much easier to follow—"Adaptive control processes; a guided tour" by Richard Bellman: Oxford University Press, 1961.

'I am afraid this list is rather lengthy and constitutes quite a considerable piece of homework. I would however like to encourage Mr White and suggest that it may well be worth while.'—EDITOR

* *Control:* May, p. 99: June p. 92.—EDITOR

Americans' fancy

SIR: As near as I can recall, Draper and Li deliberately coined the word 'optimalize' to avoid confusion with Webster's definition of 'optimize'. Personally, I'm not sure there is any likelihood of confusion, but the word seems to have captured the Americans' fancy. I think we have a liking for intensive word forms.

L. R. AXELROD
PROJECT ENGINEER
Powers Regulator Co., Ill., U.S.A.

● Uncontrolled, *who raised this subject in* Pick-off *in our May issue, writes: 'I am grateful for this explanation, and I share Mr Axelrod's doubts about the likelihood of confusion. I should myself prefer to accept the infinitesimal risk and use the less laboured word. I am all for evocative word forms—and Americans have contributed many to the language—but I do not like adding syllables where they do not effectively add meaning'.*—EDITOR

New educational approach

SIR: Dr. J. Thomson's 'Viewpoint' in the June issue of *Control* referred to a modest beginning at Northampton College, London in 1962 with a new educational approach to the problem of developing leaders of instrument design project teams.

As this announcement was made, agreement was expressed by a joint committee of the Scientific Instrument Research Association and the Scientific Instrument Manufacturers' Association to the detailed proposals of the College for a course to be started in 1962.

This course will be for students who at entry should

(i) be graduates in an appropriate discipline,
(ii) have relevant industrial experience,
(iii) be expected eventually to lead the technological advances in instrument design, development and research.

The course provided will consist of one year on instrument design and development leading to the Postgraduate Diploma of Northampton College, London (D.N.C.L.). For those who wish to continue their education further, an additional two years may be spent in the students' employing organization on a design, development or research project or projects under the guidance of suitable industrial and college supervisors. This could lead to a higher award such as the Membership of the College of Technologists (M.C.T.).

A brochure describing the course more fully is in preparation and those wishing to receive a copy when it is ready should communicate with the College in St. John Street, London, E.C.1. G. M. E. WILLIAMS
Northampton C.A.T.

Look at Britain

SIR: I wonder whether your American Correspondents have been keeping their eye on British literature? The graphical method they describe in your May issue (page 116) is identical with that proposed by K. V. Diprose in 1952 (see page 304 of 'Automatic and Manual Control', edited by A. Tustin (Butterworth's)). A practical application of the method was given by D. E. Turnbull in an I.Mech.E. paper over two years ago ('Response of a Loaded Hydraulic Servo-mechanism', 16.1.1959). However, there may be some points of innovation that I have overlooked, and I should be grateful for your Correspondents' comments. R. K. MANSON
Hatfield, Herts.

● *Our American Correspondents write: 'We appreciate Mr. Manson's comment about our notes on the graphical solution of nonlinear systems. Actually we had not been aware of the earlier presentations in the British literature of this method. It was known to us, however, that the method was not new, as is evidenced by the reference to Paynter's exposition which was published in 1952. It was our feeling that this technique can be extremely useful, and yet is not as well known as might be expected. Hence the article was included more for the purpose of making more engineers aware of it, rather than because of its novelty'.*—EDITOR

VIEWPOINT

G. D. S. MacLellan, Rankine Professor of Engineering in the University of Glasgow, says that to provide the control system designers of the future we must . . .

STRENGTHEN POST-GRADUATE SCHOOLS

Expenditure on all forms of education is rapidly increasing. There is to be higher pay for teachers, more widely available State aid to students, special Treasury grants for university expansion, and more funds at the disposal of D.S.I.R. for advanced study and research. Are these and similar developments sufficient in the present era of the 'automation revolution'?

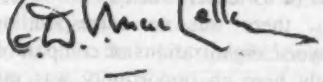
What *are* the needs? Many have expressed their views and made their estimates. Here I want to focus on one particular aspect of the problem: the education of those who are to be capable ultimately of control system design, taking advantage of developments in measurement technology, in data processing techniques and in all forms of actuating devices. A first attempt at a specification of the desirable qualifications of such people suggests an impossible educational task: they must have at their disposal a wide range of mathematical techniques; a more than nodding acquaintance with modern physics and physical chemistry as well as a firm grasp of the principles of classical physics and chemistry; a good knowledge of dynamics, thermodynamics, fluid mechanics, applied electricity and the properties of materials; and an understanding of the capabilities and the potentialities of computers. Here is plenty of scope for the professional undergraduate! The answer is, of course, to be found in team organization of specialists with a sufficiency of common knowledge to be able to 'communicate'.

Sir Willis Jackson, in his recent Viscount Nuffield Lecture before the Institution of Production Engineers, put in a plea for more broadly based undergraduate courses. These are most certainly needed, but the necessary consequence is post-graduate study for those who seek careers in advanced technologies such as that of automation. To provide appropriate scope and guidance for these advanced studies we need much stronger post-graduate schools than almost any that exist at present in the fields of engineering and applied science.

What is holding back their development? In too many cases it is the natural impatience of industry to pick the fruit from the educational vine before it is ripe, and its reluctance to nurse the soil and to provide the props which could lead to greater harvests in later seasons.

Much needs to be done, but two suggestions must suffice here. Industry which has made a significant impact on the educational scene at undergraduate level with industrial scholarships should be encouraged now to transfer its attention and more of its available resources to the provision of scholarships for post-graduate study and research; and a national fund for research grants should be established to aid investigations in the fundamental technological problems of automation.

Both these suggestions are made because of certain limitations in present facilities. The D.S.I.R. does, of course, allocate substantial funds to both purposes, but its method of working appears to be limited by the need to achieve uniformity of treatment over the whole field of science and technology for which it is responsible. While the present value of D.S.I.R. studentships may be adequate for maintenance purposes it is almost impossible to persuade a graduate with high honours to start work at about £400 per annum when he is being offered twice as much by industry for his immediate services. On the research grants side no Research Association can be obviously identified as a potential supporter of fundamental work in control engineering and automation. In consequence the universities are liable to find themselves relying more heavily on State support in this field than in some other branches of engineering science. The launching of an appeal for £250,000 a year by the newly formed Civil Engineering Research Council is an example of the kind of development which might be appropriate. Are there not tasks here for B.C.A.C.?



There were many useful lessons for the control engineer at the B.C.A.C.'s first conference, and the occasion drew attention to factors as vital as technology to success in automation

Automation—men and money

by **G. M. E. WILLIAMS** B.Sc., A.M.I.E.E., *Northampton C.A.T.*

THIS CONFERENCE WAS THE FIRST MAJOR PUBLIC EVENT arranged by the British Conference on Automation and Computation since the latter was reorganized last autumn.

About 250 people attended the conference on behalf of some 150 organizations, ranging in size from government departments and Unilever downwards. The distribution of types of office held by individuals in industrial employment is shown in Table 1, while Table 2 gives the relation between the numbers of individuals from each main kind of organization.

TABLE 1

	%
Directors of companies or equivalent	17
Managers and chief engineers	30
Accountants and financial staff	22
Production engineers, o. and m. specialists	18
Research staff	5
Education and training staff	5
Personnel and welfare officers	1
Statisticians and operational research staff	2

TABLE 2

	%
Employers in government or industry	71
Educational institutions	7
Press	7
Trade unions	6
Industrial research associations and services	5
Employers' organizations, productivity organizations, constituent bodies of B.C.A.C., and miscellaneous—1% each	4

Table 1 suggests that, of those present, a high proportion were in positions of direct influence on policy and executive action which might be concerned with the introduction of automation. The interesting feature of Table 2 is the strength of trade union representation. It is unfortunate that although the T.U.C. was directly associated with the organization of the conference, and several of its leaders such as Mr W. J. Carron presented papers, there was no corresponding response from employers' organizations of comparable national stature —surely here an opportunity was missed to raise the issue of automation to its full importance in determining how well we may live today and tomorrow. It must be said, however, that B.C.A.C. achieved one of its objectives, inasmuch as the theme of automation was a live one in the major organs of the national press for four consecutive days. Albeit more attention was given to the papers of the trade union contributors and related issues and discussions than the balance of the work of the conference represented, this is not much amiss in view of the interests of the working public who support the press. The excitement had not sufficient impetus to carry it into the serious Sunday newspapers, which could have provided a welcome review. Indeed, the whole subject of production technology, of which automation is the most sophisticated expression, lacks glamour in Great Britain, and this is a brake of incalculable effect on the rate of development—except that if there was no such brake one would expect more rapid progress. We need to stimulate the whole nation to interest as it responds to other technical and scientific progress. For the young, we need an automation Dan Dare, perhaps doing prodigious feats of output by inspired prestidigitation of push-buttons, while the baffled and unscrupulous competitor is buried in agony in a heap of unrectifiable rejects, unable to relax the smooth, relentless pressure of his adversary. For the more mature there should be 'Eye on Automation', as well as keeping the other one on research through the medium of television. It was encouraging to hear from one visitor to the conference that a formal suggestion from one quarter for the use of the proposed third television channel is to put it entirely at the disposal of industry for training and general developmental purposes. This would add strongly to the good work which the monthly publication 'Target' does already and could be of value in broadening general knowledge of the great variety of modern production techniques of which our industry is rightly, though sometimes coyly, proud.

Ministerial view

Lord Hailsham opened the conference in the evening of Tuesday, 27 June, in the Royal Hall of Harrogate. One noted the preponderance of grey or bald heads in the audience, unlike, for instance, the more evident youth found at a meeting of one of the institutions on what Lord Hailsham called the mechanical or theoretical aspects of automation technology. These aspects, he said, this conference would take for granted. In the two and a half days of papers and discussions which followed, grey- or bald-headed ideas were conspicuous by their absence. Lord Hailsham made a sound speech, reviewing the national situation in relation to the rest of the world, and basing his case on the familiar but none the less realistic theme that 'our future depends on seizing and remaining in the lead in industrial design, technology, production and salesmanship' . . . 'Our aim should be to remain at least one move ahead at every stage . . . From this point of view automation is a necessity'.

He went on to dwell on his remark that automation was no longer a word of suspicion. (In later discussions this view was not always supported in the conference.) He had one particularly good passage where he said '. . . . the essence of the matter is not the substitution of machinery for skill. It is the development of more skill in the use of machinery . . . To an alert and forward-looking industry, automation should involve headaches, but not heartaches—either for management or for labour'. His remarks ended with a concise catalogue of references to the nature of the flux in human relations and duties in industry which automation sets in train, and with it the corresponding vast effect on education and technical training. Sir Walter Puckey, chairman of B.C.A.C., and of the conference, had introduced Lord Hailsham, and now he thanked him for so apt a start to the three days to follow. Those present then adjourned to the Royal Pump Room for an official reception by the Mayor of Harrogate, and a chance to see who else had come along to the meetings.

Visitor's-eye view

Once upon a time we used to have conferences which were simple affairs, one paper and discussion taking place at a time. Nowadays practice has changed, and several sessions run simultaneously. Despite the endeavours of organizers, it is rare for these sessions to be entirely separate in appeal, and visitors are torn by the conflicting attractions of one and another paper, usually inadequately specified by the titles. At Harrogate this problem was made worse by a mystifying unwillingness to release the papers to those attending until the morning of the last of the three days. As most of the speakers read from their papers verbatim, the point of withholding the papers was lost on many present, and the discussions would have been easier if they had been in the hands of the audience at the time. Most of the papers were interesting and well presented (although the paucity of visual aids was out of keeping with Lord Hailsham's remarks on the vast effect of automation on education). There were four main lines of study at the conference, namely, economic aspects (a) internal to the firm and (b) in the wider context; and social aspects (c) internal to the firm and (d) in the wider context.* In each of the five successive sessions, over two a half days, one paper on each of the four aspects was presented simultaneously, so the following is a one-visitor's-eye view of the proceedings, directed by an estimate of what of the menu was most likely to stimulate a production technologist and control engineer.

Mr Brech's paper on the first morning on 'Forecasting requirements for the firm' looked a sound, sober statement of what a management consultant sets out to do in studying a new situation and making recommendations for action. In particular he remarked on the value of statistical techniques in forecasting and suggested the need for research into economic methods of programming the use of these techniques on computers. While this was going on Mr Brown reviewed the national economic implications of automation based on data collected at Cambridge and Mr Clegg spoke on the deep changes likely to arise in the basis of systems of payment to labour. He was not impressed by the flexibility of employers nor trades unions in these coming circumstances. There was a lively discussion in which changes in career prospects were raised and Mr Landon Goodman let off one of his provocative worries. He does wake a meeting up, even if some people fume at him a little for doing it in his own way.

Operative selection and training

The session I chose for the first morning was Mr Crossman's on 'Operative selection and training for automation'. He took a little while, as he said himself, to get into his subject by way of definitions of terms, some references to his practical observations in industrial plants and to Dr Jaques's 'The Measurement of Responsibility'—a report of studies at the Glacier Metal Co. Ltd. Mr Crossman discussed level of skill, saying that manual control of a process required little manipulative skill, but the operator was called on to make 'discretionary judgements' in Jaques's sense. The operator of an automatically controlled process, however, was a trained observer of the unmeasured symptoms of incipient unreliability in plant and controls: Mr Crossman's criteria in such plant were process efficiency and reliability.

He had some interesting points to make on selection and training of process operators. Taking operators from a pool of labour and trying them out on the job showed that correct methods of choice were important, and little work had been done in this connexion. Those who found the work beyond them voluntarily withdrew, and he quoted 40% lost so in one case.

For automation he felt that job specification with

* The titles and authors of the papers are given on p. 109.

great care and detail was essential; analytical testing was difficult and simulated plant testing might be the solution. He gave five qualities required in a process plant operator: a certain level of intelligence, numerical or space perception, aptitude for control skill, personality factor, and interest in work. Personality factor included a responsible attitude to the job, stability in crises and in monotonous conditions and the social skill of communication.

He favoured systematic training to meet the job analysis and roving instruction on site. He said that, to date, class-room instruction had not been observed to affect operators' abilities, particularly teaching simple basic science did not seem to develop them. There was a practical difficulty in roving training on site in that opportunities for some experience, e.g., blowing-in of a blast furnace, were rare. Verbal description of such events was not helpful, but histories of crises could be useful, although rarely available.

This paper produced a good discussion in which there was support for my view that plant operators and maintenance workers should be chosen from types of applicant at present often rejected as being inadequately qualified, the point being to ensure that these workers were fully extended by their jobs. They were then likely to feel as though they had purpose in their work and would be less prone to move to other work. It was noted that when initiating such a policy of labour recruitment there was required prior detailed description by technologists of diagnostic and corrective action on equipment and plant. Finally, Mr Crossman's contribution and the discussion must not be viewed in isolation from other techniques of improvement of plant operation, such as design for ease of control.

Education and automation

The set piece for the afternoon session on the first day was the paper on 'Education and Automation' by Mr A. A. Part, Deputy Secretary at the Ministry of Education. This paper gave an attractive description of the work of higher educational establishments, universities, C.A.T.s and technical colleges, in the fields of automatic control, instrument and control engineering, applied mathematics and computing, ergonomics, business and management training, mainly for the scientist and technologist but also for the technician and maintenance craftsman. It was pointed out that control engineering transcended the traditional disciplinary boundaries of mechanical, electrical and other branches of engineering. The author peppered his remarks with some delightful humour, and emphasized the need for stimulating industry, those in employment, and specially school-leavers, to an interest in automation and realization of the benefits of educational courses directly related to it. It was good news to learn that the Minister of Education is taking action to improve information about careers and avenues to them for boys and girls soon to leave school, since prospects in automation technology are among the best. The paper did not deal with production *per se* as an educational topic, and it would have been interesting to hear Mr Part on this subject, which is complementary to the activities he described.

It was a pity that Mr Part's paper was not given the standard of discussion which it deserved. While discussion was in progress, it was pointed out that there were occasionally difficulties in recruiting undergraduate-course students in control engineering as the qualifications gained in such courses did not at present carry with them clear satisfaction of the requirements for professional membership. Mr Part replied that this was a problem presenting some difficulties, and the Society of Instrument Technology would be meeting the Ministry shortly to discuss the matter.

Elsewhere during this afternoon session Dr Risk described the assessment of profitability of automation projects in terms of the accountant, Professor B. R. Williams tackled the relation of automation to the scale of industrial enterprise, and Mr J. L. Jones of the Transport and General Workers' Union used block capitals to say among other things that THERE HAVEN'T BEEN ANY CHANGES in national wage structures related to British revolutionized production methods. He had the lion's share of the national press reports next day, with his remarks about wages.

Practical problems

On the second morning I chose Mr Stuchbery's 'Physical requirements of automation'. At least one of his audience misunderstood this title until the paper was presented, and it proved to be written from the heart—about real practical problems in the automation of metal-box manufacture—supported by some interesting historical matter on early newspaper printing, paper making, and finally, modern types of food canning. The paper dwelt upon the need for storage in the layout and operation of transfer line manufacture of parts. It also assumed that redesign of the product was permissible and an integrated part of the development of such methods of production. Mr Stuchbery is to be congratulated particularly on his successful insistence on the use of a visual aid to illustrate his paper, which would have been lost otherwise. The discussion was rather diffuse although there was fairly frequent reference to the need for design for production and the problem of educating personnel in the art.

Mr Millson released plenty of statistics in his internal comparisons on the speed of automation. It seems that the audience divided on issues of fact after he had spoken, and a quite lively time was had by all. Dr Macdonald touched on problems, some raised in another context by Mr Crossman earlier in regard to criteria for selecting operators, of the monotony and lack of inspiration of repetitive work. Mr Carron of the Amalgamated Engineering Union took a rather different view from Mr Jones on the previous afternoon. He wanted labour to accept automation willingly, with what he

regarded as suitable wage provisions. Like Mr Jones, he had good reporting in the national press on the following day.

Management structure

In the afternoon I chose Mr Burns on management structure, and he made out his case for the organic form of structure, instead of the more traditional line management arrangement, which he dubbed the 'bureaucratic'. He set out to justify this on the need for flexibility of organization in an enterprise in which the product range was no longer static and was in process of development and classification. Questioned on whether there were not still uses for line management, Mr Burns produced his results of a field study of six Scottish firms which had co-operated with him by answering a questionnaire. These showed that senior management spent from 42% to 82% of the working day, depending on the firm, in talking, and it was suggested that the higher percentages were directly related to involvement in technical progress. One had to remember that this discussion was a serious one; nevertheless, it was felt by one or two that Mr Tait's session on variety reduction was also worth attending. It was learnt later that Mr Landon Goodman put some pointed questions to Mr Burns about the relation of his argument to the management of automation, and that Mr Goodman was not carried by the reply obtained. Mr Tait gave a solid defence on such matters as application of overheads to development charges and pointed out the need for research into the relation of the fall of efficiency and rise of costs associated with diversification of the product ranges.

In another session, Mr Schumacher was trying to be convincing about the unlikeliness of being able to forecast—and remarking that this fact made life interesting. Dr Lupton's paper carried the remark 'Technological change is a powerful dissolver of social structures'.

After the day's discussions there was a program of films on automation but none of these showed great distinction except Walt Disney's 'Think of the Future', which pointed one lesson in eight minutes running—look how much better life is now than it was then.

And so to the last day; Mr Jacobsen of Normalair with fascinating case studies. They all pointed in general to the unexpectedness and indeterminancy of results after pre-programing of automation introductions, all the surprises basically stemming from human reactions and behaviours after the introductory phase. His moral, that ever more care and rigidity of attention to a logical sequence of development is essential, was well taken. The cases were not meant to portray good examples of automation practice, but to display the mistakes of policy and planning, particularly as they fell short of the implications for labour and wages policies and developments. Here, there was an affinity with Dr Emery's paper on 'Social aspects internal to the firm'. Mr

Sir Walter Puckey, Chairman of the B.C.A.C. and the conference (left), with Lord Hailsham, Minister for Science

Reinoud gave the only paper from a foreign source, on the effects of automation on postal and telecommunications staff and operations in the Netherlands.

A flick of the whip

Now almost all was done. We repaired to the Royal Hall where we had first met three nights before, and listened to a masterly summing-up by Sir Walter Puckey of the 'torrential verbal downpour of the last few days'. His remarks contained some memorable points:

Automation is disintegrated into many specializations: B.C.A.C., has the task of creating common purpose for uncommon people.

The fears of redundancy voiced at the Margate conference in 1955 had not been realized The full effect of automation was as yet nowhere in sight.

The productivity of the white-collar worker must be rapidly increased, without heading into the problems which had beset the mechanization of the factory, as automation was in fact creating more white-collar jobs.

The expected increase in shift work could create problems.

There must be new thinking about wage structures, about management and the planning of capital development. Better organization and greater investment in human skill were equally important.

The educational spectrum was being split more and more into narrow bands. Educational courses were required preparatory to the coming changes.

Overall, as *The Times* said, Sir Walter administered a flick of the whip to the trade unions and the Government.

Was it a success? I think we can claim that it was. It gripped the national press for a few days without the sensational and ill-informed treatment which attended Margate in 1955 and after. It raised to the surface many problems which concern us all, particularly the control engineers, in the field of management of processes in which automation is applied in depth and breadth. There was more than one firm well represented at Harrogate which has vital and urgent decisions to make about management: are foremen needed, what wages shall be paid, from what field shall operators be recruited, what is the answer to monotony, what does the manager of the plant *do*?

'The full effect of automation is as yet nowhere in sight'. My word, yes, how true that is. And there is just a little matter of stirring up yet more activity in favour of automation, in all facets, in all places, until today's stream becomes the torrent of tomorrow.

Some of the automatic control needed in the fertilizer industry is out of the general run. Instrument engineers in other industries may profit from this account of problems that have been met and solved

Enclosed metering room, with all flowmeters and control valves for complete plant

Instrumentation and control in the fertilizer industry

by **J. C. FARQUHAR** B.Sc., A.R.I.C.
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UNTIL RECENTLY, THE FERTILIZER INDUSTRY HAS NOT MADE great use of instrumentation and automatic control. The reasons are not far to seek. Local conditions in fertilizer works are damaging for instruments, mainly because of dust which is not only fine, penetrating and abrasive, but also hygroscopic, sticky, and very corrosive to steel, copper and alloys, aluminium and alloys, and zinc and alloys. Corrosive vapours containing fluorine and chlorine are present where phosphate rock is reacted with acid to form superphosphate or phosphoric acid. In addition there is serious vibration caused by heavy rotating mixers, granulators, coolers, and driers, these being sometimes equipped with hammers, and from various mills and vibrating screens.

Another reason is the comparatively small size of many works. They are usually near water transport for taking in raw materials, and near centres of consumption to reduce transport costs. It was hard to justify adequate instrumentation staff at such small units, particularly when the processes employed were, until recently, very simple: but, because of the difficult conditions, instruments of any complexity could not continue to function without specialized supervision and maintenance.

There is also the great difficulty of obtaining reliable primary measurements. For instance, it is not easy (with anything short of a load-cell installation) to measure the level in a hopper when the character of the contents varies from fluidized to sticky and caking. Recently ammonium nitrate has been introduced as a fertilizer ingredient. This is handled as a concentrated solution which must be kept hot and freezes at 86°C. It demanded solution of a number of problems in connexion with flow, pressure, and level measurements.

To overcome these problems and difficulties required (and still requires) skilled manpower and experimental work, both of which are expensive. The expense did not seem to be justified until the introduction of newer and more complex processes forced the issue.

It is not possible, in the course of a single article, to cover all the processes used in the fertilizer industry. It is proposed, therefore, to deal only with some parts of the processes and instrumentation which are characteristic, and not the others. For instance, no mention will be made of nitric acid and ammonium nitrate manufacture, since the instrumentation of these plants follows conventional continuous chemical plant practice.

TWO AUTOMATIC CONTROL APPLICATIONS

Two examples of automatic control have been selected for description because these are both a little different from the usual run of process control applications. They are (i) air-heater and air-drier control, and (ii) granulation control.

Air-heater and drier control

In other industries, counter-current driers are usual because of their higher thermal efficiency, and also because this kind of drier acts to some extent as its own dust-collecting system, some of the dust produced being de-

posited on the wet material. However, in the fertilizer industry, co-current drying is often used. Furthermore, it is necessary to control the temperature gradient through the drier by close control of both inlet and outlet gas temperatures. The control problem therefore becomes rather more interesting. The system finally adopted is shown in Fig. 1.

TRC.1 is a two-term temperature-controller which keeps the drier inlet temperature to within ± 5 degC of the desired value by regulating the amount of diluting air added to the products of combustion of the oil-fired air-heater. In the direction of decreasing air temperature this controller is limited by the capacity of the diluting-air fan or the i.d. fan, whichever is the least. The practical limit for increasing temperatures is set by temperature restrictions for air-heater and ducting brickwork, i.e. the controller would easily be able to achieve a temperature in excess of that required at the drier inlet.

PC.1 is a sensitive furnace-pressure controller set to maintain the draught at the material inlet chute at about $-0{\cdot}05$ inH_2O, i.e. low enough to prevent escape of fumes and not so low as to draw appreciable quantities of cold air in through the inlet chute.

TRC.2 is a three-term controller with thermocouple extending well into the drier shell to prevent errors caused by cold air leaking in through the end hood. It provides control to within ± 2 degC of the desired value. In some plants it controls the fuel oil and combustion air in parallel. In other cases, the fuel oil only is controlled, the combustion air remaining fixed. Since there is always

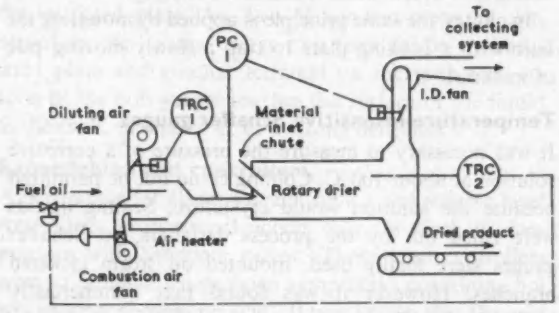


Fig. 1 Air-heater and drier control. (The 'collecting system' is for dust)

a very large amount of excess air, no efficiency is gained by fuel–air ratio control. The only justification for linking oil and air is to obtain constant flame characteristics.

It will be noticed that there are three interacting control loops on this one system. However, no trouble with control interaction has ever been experienced because the ultimate periods of the three loops are very different.

The more usual control arrangement for co-current driers is to make TRC.1 control the fuel oil and TRC.2 control the dilution air. It was decided not to use this system because nothing was to be gained from the control point of view. It had the disadvantage that, if the incoming material flow were to fail, the whole drier would tend to rise to the temperature set by the inlet controller, which

Fig. 2 Enclosed control room with glass front. Air-heater instruments in centre, solids-level and flow instruments on r.h. wing, and plant-interlocking lights, recording ammeter and multipoint temperature recorder on l.h. wing

would be excessive for the drier. Certainly a high-temperature shut-down would be fitted to TRC.2 but there seems to be no point in using an inherently unsafe system protected by a shut-down contact. The system actually employed has control action which fails safe in the event of sudden reduction in load, and has the further advantage that it can easily be used as a single-loop control system, i.e. using TRC.2. only. Also it is very straightforward and easy for the operators to understand.

Granulation control

In the blending and granulation process, powdered solid fertilizer ingredients and fluid ingredients are combined in fixed proportions and converted into small spherical granules. The granules (each containing all the ingredients in the desired proportions) are then dried, cooled and screened.

Material which is too fine for sale (' fines ') is returned to the granulation process, and material which is too coarse (' oversize ') is in some plants cracked until it passes the product screen, and in other cases pulverized completely and returned along with the fines. For products which involve the addition of a liquid ingredient a recycle of fines (or pulverized oversize) is helpful in absorbing the liquid ingredient.

The object of the process is, of course, to produce material of which as much as possible is within the size limits acceptable for sale. The average size of granules is varied manually by regulating certain conditions. But here the most significant fact is that, in addition to the controlling agents mentioned above, an increase in fines return-feed to the granulator results in the production of smaller granules and even more fines. A reduction in fines recycle produces more oversize and less fines.

In cases where the oversize is not completely pulverized and returned, the control engineer will at once recognize a closed loop with positive feedback, resulting in instability. In the other plants where the oversize is completely crushed and returned as fines, this particular recycle is equivalent to negative feedback.

In applying automatic control to granulation there are

two problems, the first being the elimination of positive feedback, and the second being distance–velocity lag. With regard to the latter, the granules are not hard enough to sample and screen until they have been dried, and the time lag in the drier is of the order of twenty to thirty minutes: but the human operator can judge the process almost without any lag by inspecting the moist material entering the drier. Therefore manual control has a great advantage over automatic control here. This is a case where it is better to employ automatic control (at least initially) only to fix all variables entering the system, and not as a true closed loop based on product quality.

This has been achieved in one works by providing all solid feeds with conveyor-belt weight-controllers, pneumatically operated and employing the standard 3–15 lbf/in² gauge air signal. Variable-area linear-scale flow transmitters are used for the fluid feeds, and all feeds are pneumatically ganged so that the plant throughput can be adjusted by one setting knob. Later on it may be found possible to use overall automatic granulation control in cascade with the controllers for the variables affecting granule size.

Positive feedback is at once prevented by controlling all the variables entering the granulator, since one of these variables is the total amount of fines. Though this cuts the closed loop, it does not eliminate the disturbance. It merely confines it to points downstream of the returned-fines hopper, which acts as surge capacity. Therefore an automatic control loop has been installed whereby the returned fines are kept constant by diverting some of the product granules to a pulverizer to make the total fines up to a constant amount. Naturally, this is not quite so important in plants where all oversize is pulverized, thus helping stability by providing some negative feedback.

SOME INDIVIDUAL INSTRUMENT APPLICATIONS

A few individual instrument applications are given below as representative of some of the problems which have been encountered and solved. They may prove interesting and useful to instrument engineers in other industries.

Temperature sensors for granular heaps

Problem: to obtain an accurate record of temperatures at various points in large heaps of powdered and granular materials. These heaps are afterwards removed by crane grab or mechanical shovel, sometimes assisted by blasting. Therefore the temperature element is frequently damaged or destroyed, and must be cheap and robust.

The solution is extremely simple and effective. Tough rubber-covered multi-strand copper–constantan compensating lead is used to form the measuring couple itself, and therefore serves the double purpose of couple and compensating lead. The couples are formed by baring and soldering the junction, and then taping over for insulation. The wires are suspended in the heap at the desired points, and connected to a multi-point strip-chart electronic recorder.

For accuracy, temperature–e.m.f. characteristics are measured for each batch of wire. These have been found to be remarkably uniform, and amply justify the choice of copper–constantan.

Temperature of granular material in motion

Problem: to obtain an accurate, continuous, temperature measurement on powdered and granular solids moving on conveyor-belts or falling down chutes. Various devices were tried and failed because of abrasion, damage by large lumps of material, sticking of material to the sheath, and failure to contact the material thoroughly. At one stage infra-red radiation measurement was proposed, but the emissivity of the material was too variable.

The solution again is very simple and effective. It was found that the material did not stick badly to the polished stainless steel covering of a standard Sangamo-Weston resistance bulb, though the bulb was damaged by abrasion and by large lumps when not carefully mounted.

For conveyor-belts, the best method is to mount the bare resistance bulb vertically on a spring, or weight-loaded support, so that it can swing out of the way when struck by large lumps. The end of the bulb dips into the material and is about an inch clear of the belt itself. The most important point is that a stainless steel strip about an inch wide must be mounted on the same support as (and about an inch downstream of) the resistance bulb. This strip acts as a plough, and, if correctly placed, it causes the sensitive tip of the bulb to be covered deeply by a slowly moving stream of material, thus ensuring minimum abrasion and maximum accuracy.

In chutes, the same principle is applied by mounting the bulb with a backing plate to trap a slowly moving pile of material.

Temperature-insensitive Schaffer gauges

It was necessary to measure the pressure of a corrosive solution at about 100°C. Cooling could not be permitted because the solution would crystallize. Sealing liquids were ruled out by the process designers, so Schaffer gauges were finally used, mounted on steam jacketed branches. However it was found that commercially available Schaffer gauges were temperature-sensitive. One example gave a +30 lbf/in² error at all pressures, for a temperature rise of 80degC, the range of the gauge being 0–200 lbf/in² gauge.

The problem was solved by replacing the stainless-steel thrust-pin (between the diaphragm and the pointer gearing) in the gauge with a pin made of Invar. The maximum error is now ±2 lbf/in² for a temperature rise of 100degC.

Electrodes for continuous level-indicators

Capacitive continuous level-indicators have a limited application in the fertilizer industry because of variations in the dielectric constant of the materials handled, and in some cases because an adherent conducting coating of hygroscopic dust is formed over the whole electrode.

Apart from these limitations, however, commercially

available electrodes were found to be unsuitable for service in fertilizer hoppers. The cause of failure was insulation break-down resulting from the heavy strain on the electrode. The moving material in the hopper produces great tension in the electrode, and the force is transmitted from the wire through the insulation to the anchorages at both ends.

Although it is too early to claim complete success, this particular problem appears to have been solved by a special design of polythene-covered electrode. The insulation is not required to bear any strain at the anchorages. At each end, the insulated wire passes through a cable gland in a Chemidus block. Inside the block, the wire itself is anchored to take all the strain. For attachment to the hopper, a ring bolt is screwed into the block.

Tank dipping—hot concentrated solutions

Problem: to devise an accurate method of tank dipping for accounting purposes. The large storage-tanks contain a molten solution of ammonium nitrate at about 100°C. This solution creeps and crystallizes very readily, which rules out the suspended-float type of instrument—at least for this purpose where maximum accuracy is required. It is considered that, in this case, hydrostatic methods would not provide sufficient accuracy.

The method finally adopted gives direct results to within $\pm 0{\cdot}1$ in and is cheap and easy to operate. It is an ullage method, and consists merely of an insulated plate mounted on one of the dip holes. A stainless-steel gauger's tape (with stainless-steel bob-weight) is allowed to run down into the tank, rubbing against the edge of the insulated plate. An Avo Minor test meter is connected on the ' ohms ' range to a terminal on the insulated plate and another terminal on the tank top. As soon as the bob weight touches the surface of the liquid in the tank, the meter gives a strong deflexion.

Expendable level controllers

A need arose for about a dozen robust and reliable level controllers, proportional action only, to work in conjunction with Saunders valves. These level controllers were to be mounted on open sump-tanks containing hot wet-process phosphoric acid. It was known that the acid would occasionally foam over the tanks to a height of several feet, and would most probably submerge the level controller itself in acid foam. Since it is practically impossible to protect a controller against damage under these conditions, it was decided to design an instrument simple and cheap enough to be expendable.

The design finally adopted is a pneumatic force-balance displacement float type, as shown in Fig. 3. A Chemidus (unplasticized p.v.c.) float is suspended from one end of a lever which has a thrust-rod at the other end. The thrust rod applies, to a Kent pneumatic load transducer (Type LCF.4898), a force which is proportional to the float weight.

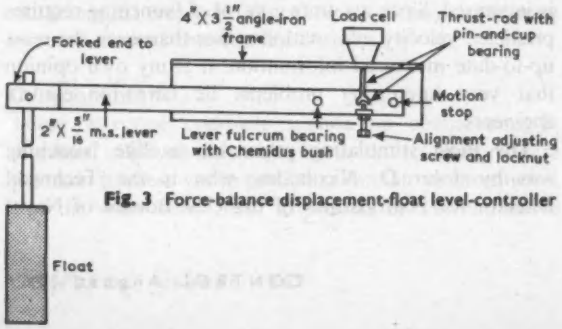


Fig. 3 Force-balance displacement-float level-controller

The lever is carried in a plain bearing with a Chemidus bush which obviates the need for lubrication and prevents sticking owing to corrosion. There is a simple motion stop consisting of a pin through a clearance hole in the lever arm. The thrust rod itself has a pin-and-cup bearing which requires no lubrication and does not bind.

The output pressures of the load cell for high and low levels are fixed by float weight and dimensions and liquid s.g. and by the position of the lever fulcrum. The proportional band (or range, when the instrument is used as a level transmitter) is, of course, fixed by the float depth.

The device has proved entirely satisfactory and it is remarkably accurate as a level transmitter. A secondary advantage, when using Saunders valves, is that the output pressure can be arranged to suit the line size and line pressure of the particular valve, thus obviating the need for a 3–15 lbf/in² positioner in many cases. Also the conventional air set is not required, though it is an advantage if the air supply pressure is reduced to prevent damage if the controller is mishandled, e.g. by standing on the float.

LOCATION AND PROTECTION OF INSTRUMENTS

Whenever possible, instruments are grouped in enclosed control rooms which are supplied with clean air under slight pressure from ventilation fans. The air is either filtered, or drawn from outside the buildings. An unusual feature is that it is not only instrument panels which are placed in the control rooms, but also as many of the line-mounted instruments as possible. For instance, by arranging for process fluid lines to pass through the control room, it is possible to enclose and protect the flow transmitters, control valves, and most of the locally mounted pressure and temperature indicators.

Because of lack of space, it is sometimes impossible to enclose a panel. Such panels are always provided with internal heaters and air purge, and are sealed as carefully as possible to minimize ingress of dust. Relays inside the panels are preferably of the enclosed and sealed type. If not, they are mounted in dust-tight boxes with contacts in vertical plane to minimize adherence of dust.

Of course, many individual items (such as power cylinders, control valves, pressure gauges etc.) must remain locally mounted in various parts of the plant, exposed to severe conditions. Although it may seem crude, by far the most practical protection for these items has been found to be polythene bags, tied at the neck, of polythene sheeting made in tubular form and tied over the instrument as necessary. This is particularly effective with pneumatic instruments having a small air purge, which is one reason why pneumatic control is preferred to electrical control in fertilizer works.

Last month's meeting of the Brit.I.R.E. did not deal directly with the control side, but the many interesting papers showed that the launching of satellites and their stabilization in orbit demands first-class control engineering

Stepping into space

by **P. M. THOMPSON**, *The Plessey Co.*

IN REPORTING THIS CONFERENCE, 'RADIO TECHNIQUES AND Space Research', for control engineers I am confronted by the difficulty that, although conducting space research successfully depends to a large extent on good control engineering, there was little direct discussion of control engineering at the conference. However, there were papers which should be of interest to control engineers because good control engineering was implied.

Before discussing some of the papers, it is worth making some remarks about the organization of the conference. One could not help being impressed by the smoothness with which the conference ran, the attention to detail, and the way in which one was kept informed about all arrangements. It is important for organizers of conferences, the purpose of which is to disseminate information, to remember to disseminate information about the conference; and with written versions of the papers available even where the text had been received very late, and news-letters which appeared in one's rooms regularly, this was done very well. The weakness of the arrangements lay in the slide projection equipment which produced a picture that was too small for any but the very best slides to be seen properly, and lack of public address equipment to reinforce the voices of the quieter speakers. In view of the way the Brit.I.R.E. organized the details completely under its control, it would be wise to consider buying their own equipment for use at conferences, and to publish standards for slides. The number of people at this conference, an important parameter in its success, resulted in an average of about 200 at most sessions, and was about right.

Launching of satellites

The papers were divided into seven sessions which filled 3½ days. They covered satellite engineering, including both systems and components, communication by satellites, extra-terrestrial measurements, and radio astronomy, and were given by speakers from many countries. The papers of most immediate interest to control engineers were those relating to the launching of satellites and their stabilization in their orbits.

The first paper, *Satellite launching possibilities* by D. J. Lyons of R.A.E., underlined some of these problems, and indicated the need for multi-stage rockets by relating the mass that can be placed in orbit to the number of stages. The speaker favoured a three-stage launcher in which the last stage provides a constant low thrust for a large part of the flight instead of the short impulsive thrust of the contemporary American third stages. M. A. V. Matthews (Ferranti), in his paper *Inertial systems in space vehicles*, illustrated an important problem of control. The measurement of launcher velocity and direction, which is an important part of the overall control loop, takes time. At present a Doppler measurement is used, and it is necessary to count a large number of cycles to obtain the high accuracy required. Thus the components of velocity are known only in retrospect, and the corrections to the orbit must be applied on the basis of a prediction. The solution suggested by this speaker was in bringing the information up to date using the short-term stability, and therefore accuracy, of inertial equipment. The difficulties with this solution are two. First, the inertial equipment may become a fairly large part of the satellite payload, and secondly the complexity of the satellite is increased. Since accurate control of launching requires predicted velocity information rather than even the most up-to-date measured information, it is my own opinion that very interesting problems lie here for control engineers.

The most stimulating paper on satellite launching was by John D. Nicolaides, who is the Technical Director for Astronautics of the U.S. Bureau of Naval

Weapons. Entitled *An economical satellite launching technique for conducting radio research in space*, this paper started by making a case for smaller rather than larger satellites for many scientific purposes, suggesting that simple experiments are more reliable, and have a better chance of operating over long periods, than some of the more complex ones which have been suggested. Furthermore there is much sense in the philosophy of one satellite per experiment. The satellite may be flown in the optimum orbit for a particular experiment without affecting any others, and there are none of the problems associated with co-operation between various experiments with the inevitable delays. The launcher that the U.S. Navy is developing will place 25lb in a 300-mile orbit or 10lb in a 1000-mile polar orbit at a cost of 50,000 dollars. It is launched from an aircraft, and is thus independent of ground weather conditions.

Communications

Much interest was centred on the use of satellites in communication, and this was covered from every angle. There was discussion on the need for fixed-service links based on a survey of the present overcrowded, badly organized, and unreliable h.f. links. These were estimates of the growth of requirements for such services, a survey of the competition from other services, and the optimum orbits to provide the estimated services. The choice of optimum orbits is largely governed by the location of available launching sites. It was on this subject that Earl Mountbatten entered the discussion and demonstrated that he was a great deal more than merely a figurehead President of the Institution, and had both a firm grasp and a lively interest in the subject. Earl Mountbatten had come to the conference to preside at the banquet, where he once more demonstrated his skill as an after-dinner speaker. However, I must admit that, at this stage of the conference, my critical faculties were dulled by the many excellent wines which accompanied the various courses.

Returning to satellite communication systems, other subjects covered were the choice of modulation systems, and carrier frequencies, and the problem of obtaining international agreement on the allocation of sufficient of these frequencies in already highly committed bands. Of interest to control engineers, there was W. F. Hilton and B. Stewart's *The advantages of attitude stabilization and station keeping in communication satellite orbits*, and in connexion with this subject Mr Nicolaides reported a very effective method of damping nutation in satellite spins. The method, for which there is no mathematical analysis, is to mount a ring containing mercury around the satellite.

Components

There was one complete session on components in satellites, with considerable stress on reliability. Here the main interest was in particular satellite environments, e.g. the Van Allen belt. However, in *Techniques in microminiaturization*, D. H. Roberts and D. S. Campbell (Plessey) surveyed the state of a subject which may soon become of particular importance to control engineers, for it is probable that silicon solid circuits will replace conventional transistor circuits in computer, and digital control, logic circuits in a way similar to that in which transistors have replaced valves.

Measurement

During the final day, the attention of the conference was turned from the satellite and communication engineering to space physics. There were papers on measurements from both satellites and radio telescopes, which it must be remembered are as much tools of space research as satellites. The papers on measurements from satellites were concerned mainly with proposed experiments. However, there was one important exception in a paper by K. I. Gringauz (Radio Technical Institute, Academy of Sciences, Moscow), *Methods used on Soviet rockets and earth satellites for determining local concentrations of charged particles in the ionosphere and interplanetary space, and some of the results obtained*. The results of these experiments were of particular interest because they provide answers to many of the unknowns in designing further experiments.

The measurements which will be made from satellites fall into two classes; measurement of radiation in the parts of the spectrum which do not reach the earth, such as primary cosmic rays, x-rays, and parts of the radio spectrum; and also measurements of the ionosphere.

Three approaches to ionospheric measurements are:

1 to sound the ionosphere from the top in the same way as it is sounded, at present, from the ground, as proposed in a paper by R. C. Langille and J. C. W. Scott.

2 measurement of the transmission of harmonically related frequencies through the ionosphere, as reported by S. J. Bauer and J. E. Jackson, and

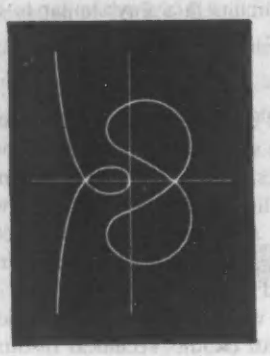
3 probe measurements in the ionosphere as proposed by R. L. F. Boyd.

The method adopted in this last approach is to measure the non-linear current–voltage curve of a Langmuir probe, and the technique adopted for this measurement is to detect the intermodulation between two a.c. signals applied to the probe. In the field of relatively low-frequency radio astronomy, F. G. Smith (Cambridge University) described his proposed experiment to shed more light on the theories of radio emission from the galaxy, and R. C. Jennison (Jodrell Bank) made an interesting proposal for using the properties of the ionosphere to obtain an aerial with a very high angular resolution.

Assessment

The papers were of interest not only to space engineers and physicists but to people concerned with most branches of electronics. I estimate that 75% of the papers were both of interesting subject matter and well presented, which is a very good score indeed.

NUMBER EIGHT OF THE SERIES PART A



The last two articles of this series have considered normal compensation techniques interpreted by the root-locus method, and this concluding article is concerned with the general use of the method to examine various situations associated with closed-loop systems

Pole-zero approach to system analysis

by **P. F. BLACKMAN**

Imperial College of Science and Technology

Equation solution and related ideas

Although previously root-locus methods have been applied mainly to closed-loop systems, the fundamental process being investigated is really the locus of solutions of equations for variation of some parameter. This principle is often useful, and also can be used to examine established results from a slightly different aspect.

As an example consider the cubic equation

$$p^3 + a_2p^2 + a_1p + a_0 = 0,$$

where the 'solution' is any value of p causing the left-hand side to become zero. The equation may be written in an alternative form as

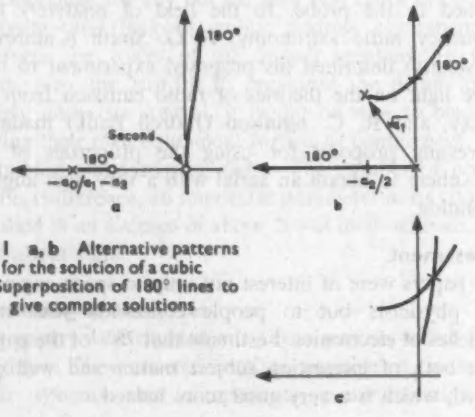


Fig. 1 a, b Alternative patterns for the solution of a cubic
c Superposition of 180° lines to give complex solutions

$$p^2(p + a_2) = -(a_1p + a_0),$$

or

$$p^2(p + a_2)/(p + a_0/a_1) = -a_1,$$

so that the process of solution now reduces to finding values of p which cause the left-hand side to be $-a_1$, and can be investigated by a 180° line plot for the pattern given in Fig. 1a. The solution values lie on the 180° lines, so, in the case shown, with an entire 180° line in the right-half plane, there will be two complex solutions with positive real parts, corresponding to unstable solutions. The 180° lines will be in the right-half plane if the pole at $-a_0/a_1$ lies to the left of the zero at $-a_2$, or in the left-half plane if the pole-zero order is reversed. Hence the relative values of $a_0/a_1 : a_2$, or $a_0 : a_1a_2$ form the criterion for unstable solutions, and this is the result obtained by the formal application of Routh's criterion.

The actual solution points could be found by using the plot of Fig. 1a, but alternatively the original equation could be written as

$$p(p^2 + a_2p + a_1) = -a_0$$

leading to the plot of Fig. 1b, which can easily be sketched[1], and finally the two sets of loci may be superimposed as in Fig. 1c, to yield the complex solutions at the intersections, leaving only the real root to be found. Also consideration of the patterns of Fig. 1

[1] See Fig. 15b, Part 5B (May 1961).

shows that, if either a_1 or a_2 is negative or zero, then there will *always* be an entire 180° line in the right half, hence *at least* all coefficients must be present and positive, which is a normal preliminary condition to be satisfied before Routh's criterion is applied. The solution process outlined above may be applied to more complicated equations, or a method of successive plots may be used[1].

Equation solution may be combined with parameter variation investigations as mentioned in Part 7 (last month). As an illustration a spring-mass-dashpot system previously considered[2] is shown in Fig. 2a, and the transfer between a force f_1 and the motion x_1 of the same mass is

$$\frac{X_1}{F_1}(z) = \frac{1}{K} \times \frac{z^2 + 2\zeta z + 1}{z^4 + 2\zeta z^3 + 3z^2 + 4\zeta z + 1}$$

where the transfer has been normalized by the substitutions $z = (p/\omega_n)$, $2\zeta = D\sqrt{(KM)}$, $\omega_n = \sqrt{(K/M)}$. It may be required to determine the natural modes (poles) of the transfer, and also to investigate their motion as ζ is varied, so the pole equation $z^4 + 2\zeta z^3 + 3z^2 + 4\zeta z + 1$ must be rewritten to isolate the parameter ζ as

$$T(z) = \frac{z^4 + 3z^2 + 1}{z(z^2 + 2)} = -2\zeta$$

The poles of $T(z)$ are at $z = 0, \pm j\sqrt{2}$, and the zeros are at $z = \pm j0{\cdot}615, \pm j1{\cdot}62$, with the general form of 180° lines shown in Fig. 2b.

The zeros correspond to the two undamped natural frequencies of oscillation of the system, and the poles correspond to infinite damping, in which case mass 2 remains stationary and mass 1 oscillates with a spring rate of $2K$. The 180° lines could be plotted exactly, but, as a practical approximation, if the pattern in the immediate vicinity of the origin is considered, the net phase angle contributed by the additional pairs is small and tends to cancel, so the 180° line may be approximated by a semicircle centred at the origin. By a similar argument the outer lines may also be approximated by semicircles. The diagram shows that the high-frequency mode is always relatively lightly damped, the maximum damping occurring for $z \simeq -0{\cdot}1 \pm j1{\cdot}5$, and at this point $|T(z)| = 1{\cdot}25$, so that $\zeta = 0{\cdot}62$. There will be a corresponding point on the low-frequency locus where $|T(z)| = 1{\cdot}25$ at $z \simeq -0{\cdot}4 \pm j0{\cdot}45$, showing that this mode is relatively well damped. The results given in connexion with Fig. 15 of Part 3 (Jan. 1961) were obtained using the diagram of Fig. 2.

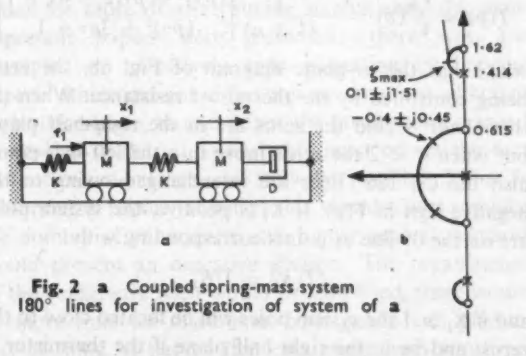


Fig. 2 **a** Coupled spring-mass system
b 180° lines for investigation of system of **a**

[1] See ref. 1, p. 129.

[2] See Fig. 15, Part 3 (January 1961).

Feedback polarity

In all closed-loop systems considered, the locus of closed-loop poles has been the 180° line of an open-loop plot. This has arisen since the natural modes of a system e^{pkt}, correspond to values of p for which the loop transmission is *unity*, which enables the natural-mode signal to propagate round the loop; for instance a sine wave oscillator will have a loop transmission of unity for signals of the form $e^{j\omega_n t}$, where ω_n is the frequency of oscillation. When a system has *negative* feedback there is a net 180° change in the loop (normally provided by subtraction at the comparison point), and the poles occur on the 180° lines of the open loop, corresponding to a total loop shift of 0°. Similarly for *positive* feedback the closed-loop poles occur on the 0° lines of the open loop.

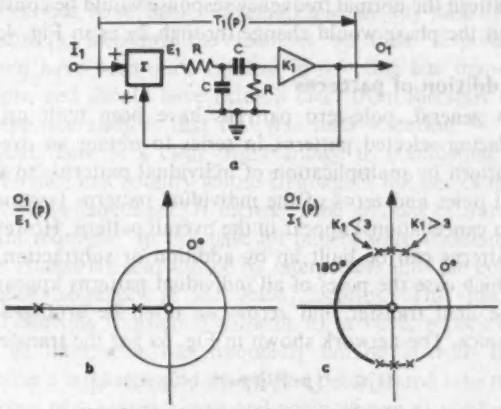


Fig. 3 **a** System with positive feedback
b Forward-path pattern for **a**
c Closed-loop pattern for **a**

The system of Fig. 3a, has a forward path transfer of the form $K_1 p\tau/[(p\tau)^2 + 3p\tau + 1]$ where $\tau = CR$, and the pattern gives a circular 0° line centred on the origin as in Fig. 3b. Since the system has positive feedback (the feedback path is positive into the comparison unit) the closed-loop poles are on the 0° line, and as the gain is increased the closed-loop poles advance towards the imaginary axis, the system finally oscillating for $K_1 = 3$. The closed-loop transfer $O_1/I_1(p) = T_1(p)$ is given in Fig. 3c, the zero in the forward path surviving into the final pattern, which again has a circular 0°, 180° line. The system of Fig. 3a could be used as the feedback path for a second amplifier with gain K_2 as in Fig. 4a, negative feedback being arranged in the second loop, and a final output taken from the error point in this loop. The complete transfer $T_2(p)$ is shown in Fig. 4b, and will contain zeros which are the poles of $T_1(p)$, and hence may be in the right-half plane, but the poles of $T_2(p)$, being on the 180° lines of Fig. 3c, will be in the left-half plane if K_2

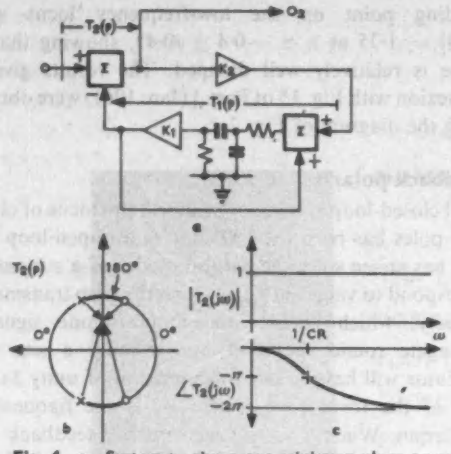


Fig. 4 a System to give a non-minimum-phase transfer
b Transfer pattern for system a
c Frequency response for pattern b

is adequate, and the overall system will be stable. In this case $T_2(p)$ would be a non-minimum phase transfer[1], and if the gains were adjusted to give a symmetrical pattern the normal frequency response would be constant but the phase would change through 2π as in Fig. 4c.

Addition of patterns

In general, pole-zero patterns have been built up by placing selected patterns in series to obtain an overall pattern by multiplication of individual patterns, so that all poles and zeros of the individual patterns (assuming no cancellations) appear in the overall pattern. However, patterns can be built up by addition or subtraction, in which case the poles of all individual patterns appear in the final transfer, but zeros can often be arranged to choice. The network shown in Fig. 5a has the transfer

$$T(p) = (p\tau)^2/[(p\tau)^2 + 3p\tau + 1]$$

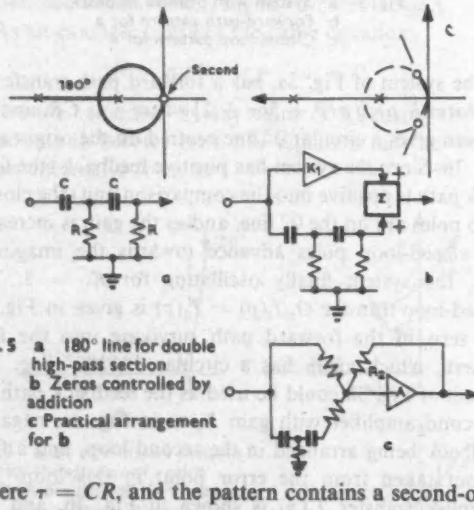


Fig. 5 a 180° line for double high-pass section
b Zeros controlled by addition
c Practical arrangement for b

where $\tau = CR$, and the pattern contains a second-order zero at the origin and real-axis poles giving a circular 180° line. If the output of this network and a portion (K_1) of the input are added as in Fig. 5b, zeros will occur along the 180° line where $|T(p)| = K_1$. With the present network, zeros are obtained with $\zeta = 0{\cdot}4$ for $K_1 \simeq 0{\cdot}07$. The entire circuit could be arranged round a single operational amplifier as in Fig. 5c, where the feedback resistance R_2 might be replaced by a further impedance network used to introduce a multiplicative pattern. Since the amplifier input is a virtual earth point, there would be no interaction between the input and output impedance patterns.

The Wien bridge oscillator

The Wien bridge oscillator gives an instance of pattern addition. The conventional arrangement has the general form of Fig. 6a, where the thermistor is considered to have a resistance aR_2, ($a \gg 1$) when cold, and a decreases with increasing voltage across the thermistor owing to heating.

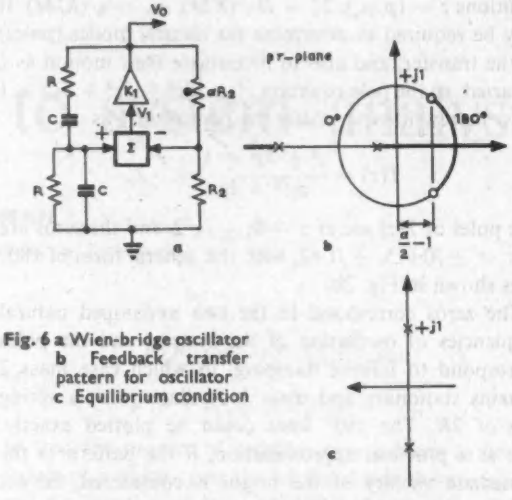


Fig. 6 a Wien-bridge oscillator
b Feedback transfer pattern for oscillator
c Equilibrium condition

The total transfer from the output V_0, through the feedback network to the amplifier input V_1, is given by

$$T(p) = \frac{V_0}{V_1}(p) = -\frac{1}{(1+a)}\left[\frac{(p\tau)^2 + p\tau(2-a) + 1}{(p\tau)^2 + 3p\tau + 1}\right]$$

which has the $p\tau$-plane diagram of Fig. 6b, the zeros being controlled by the thermistor resistance. When the thermistor is cold the zeros are in the right-half plane, but when $a < 2$ the zeros move into the left-half plane, also the 0°, 180° lines are interchanged owing to the negative sign in $T(p)$. If K_1 is positive, the system poles are on the 0° line at points corresponding with

$$|T(p)| = 1/K_1,$$

and if $K_1 \gg 1$ the system poles will be located close to the zeros, and be in the right-half plane if the thermistor is cold. This will result in an increasing amplitude of oscillation at the output, which will heat the thermistor, reducing a, and shifting the zeros—and hence the poles—back towards the imaginary axis. Equilibrium is finally obtained with the poles on the imaginary axis giving a constant-amplitude oscillation. *To be continued*

[1] See *Non-minimum phase shift networks*, Part 3 (January 1961).

Instrument men met in Budapest a few weeks ago to discuss measurement. Here is an account of their conference by one of the British delegates

The second Imeko

by **D. M. BISHOP**, *Imperial Chemical Industries*

THE SECOND INTERNATIONAL MEASUREMENT CONFERENCE (Imeko) was held in Budapest from 26 June–1 July 1961. Those who attended the first conference in November 1958 complained about the inclemency of the weather, and suggested the end of June as a more appropriate time which also suited university staff: certainly the weather was clement enough this year, with temperatures above 95°F on occasions, but equally unsuited to attendance at lectures in a building without air-conditioning. A truly magnificent swimming-pool on Margaret Island in the Danube proved a successful counter-attraction for not a few of us from time to time.

That this should have happened must, however, to a large extent, be blamed on other things than the brilliant weather and the weakness of the participants. It must unfortunately be said that in spite of the immense efforts of Professor Striker of Budapest and his Secretariat, the conference suffered from several serious defects which severely limited its usefulness, and made attendance at many lectures quite pointless.

Firstly the program was a very heavy one, and I am quite sure that the conference would have been the better for more drastic pruning so that only the more important papers were presented: there was, for example, an excessively high poportion of 'review papers' which did not in fact say anything new although each did express in one paper the conclusions reached by several workers. Against this must be set the fact that often attendance can only be justified if one is presenting a paper: although this would tend to reduce the number of participants, the higher general standard would prevent an excessive decline. The organization of the conference itself would be simplified, there would be more time for discussion, both public and private, less clashing of papers that one might wish to attend (four were being delivered simultaneously throughout).

The standard of papers can only be assessed in advance, and proper preparations made for attendance, if preprints are available at an early date, as they were, for example, before the Ifac conference in Moscow last year. In this respect Imeko was woefully inadequate: I received abstracts shortly before leaving for the conference, some preprints on the second day of the conference, and the rest at the end of the final day. The lateness was in part due to the authors' natural inclination to leave things to the last minute (and beyond), but this cannot have been universal, and in any case the organizers, knowing the facilities at their disposal, should have been quite ruthless in rejecting late manuscripts, and should have made it clear from the start to prospective authors that this was their intention.

Next there is a clear disadvantage in conducting a conference in a country whose language is not one of the conference languages. It increases the amount of translation required: in this case all papers were translated into Hungarian and thence by interpreters into the conference languages at the actual lectures. This made simultaneous translation difficult to achieve, especially as the interpreter was frequently unfamiliar with the speaker's language, and translation deteriorated into the reading of a sentence now and again chosen at random. The fault was not always only on the part of the translation service: quite clearly many of the lectures were far too long and had to be rushed and abbreviated. It seems to me to be essential at such conferences for the author to read his paper, or at least a specially prepared shortened version of it previously given to the organizers. Whatever the cause of the difficulties, it was soon evident that it was a waste of time to attend a paper in a language with which one was not familiar.

Gleanings

Since preprints were not available in advance, and attendance at lectures in foreign languages of no value, it was impossible to form any sort of general technical impression of the conference, or even of the sections of greatest interest. I propose, therefore, just to give an outline of the conference as a whole and to do what I can to discuss papers presented in English.

The conference was opened in the Rozsa Ferenc Hall (which is air-conditioned). After a large number of relatively short opening addresses of a somewhat

political nature, we had a set of technical lectures by senior representatives from France, Belguim, Russia, Hungary and U.K.; only the last-mentioned was delivered in English. It was presented by S. S. Carlisle of B.I.S.R.A. and was entitled 'Measurement the basis of automation'; Carlisle illustrated his thesis (which needs no emphasis in this journal) with many examples of measurement problems in the steel industry, and said (and I confirm) that similar problems can be found in the manufacturing and process industries.

The rest of the week was given up to half-hour lectures (including discussion!) in the Engineering Societies' Building (previously the Stock Exchange). The sections were:

Metrology and terminology—four papers
Theory and practice of instrument design—nine papers
Technology and organization of instrument manufacture—three papers
Electronic measuring instruments for general application—three papers
Border questions related to measurement and automation (sponsored jointly with Ifac)—sixteen papers
Instruments and methods for measuring geometrical and mechanical quantities, including geodetic measurements—28 papers
Instruments for measuring thermal quantities—eleven papers
Instruments and methods for physico-chemical measurements—sixteen papers
Instruments and methods for measuring electrical and magnetic quantities—eighteen papers
Instruments and measuring methods in radio engineering—ten papers
Instruments and methods for measuring radio-active radiation—eight papers

136 papers in all. It is clear that only a few of the papers presented could be of direct interest to industrial users.

In the section on theory and practice, a Polish paper in Russian by S. Orzepowski, entitled 'The application of transistorized transmitters for measuring physical parameters on rotating machinery' was, I am assured, excellent and is likely to be of interest; the only other papers in this section of any note were by B. Shackel of E.M.I. Electronics ('Ergonomics of equipment design') and J. H. Laub of California Institute of Technology ('Gas lubrication in instrument and control devices'). Of the three papers on technology and organization of instrument manufacture, only that by Professor Striker himself ('Long-range planning of instrument manufacture in a planned economy') attracted interest, but my feelings on listening were that, as rate of growth tends to be at 'compound rates', any inaccuracy of the constants would seriously vitiate the calculated results. It is nevertheless an exercise which has to be undertaken by all individual companies here (although it is probably better realized that inspired guess-work alone leads to a correct prediction), and because of this it may be interesting. In the small section on general electronic instruments, the paper by A. Ambrozy of Hungary ('Industrial applications of a statistical quality control instrument') might be of value, particularly to companies making electrical and electronic components in large quantities.

Most of the papers relating to automatic control were in German and Russian and I cannot comment. Of those in English none seemed to be of great interest: the only one I shall mention is 'Integrated measuring system' by V. R. Boulton of Aero-jet General Corporation; the most striking things about his paper were the very high precision of the transducers mentitoned, and the regrettable fact that it was the only paper in English which mentioned politics.

Interesting papers and helpful people

In the field of temperature measurement there were several interesting papers. T. M. Dauphinee presented one prepared in conjunction with Kirby and Preston-Thomas of the Canadian National Research Council: the subject, 'Ocean temperature measurements', would not seem to have any industrial significance, but the authors have developed a resistance thermometer measuring circuit which would be particularly applicable to accurate narrow-span measurements at a distance, as the effect of lead resistance is completely removed. Two other interesting papers were those by J. R. Beattie of Pilkington Bros. ('The measurement of the temperature of semi-transparent materials') and T. A. Perls of Lockheed Aircraft Corporation ('Pyro-electric transducers for heat transfer measurement'). At the end of this section was an excellent paper, the only one on flow measurement, by C. Graczyk of Poland ('The application of the Venturi tube to the measurement of the rate of flow of coal dust transported by air') which will be of interest to all concerned with the control of pulverized-fuel-fired boilers.

Two of the papers dealing with physico-chemical measurements are worthy of mention. G. Jessop and H. W. Holy of the Cambridge Instrument Company described their instrument for 'High-accuracy measurement of oxygen dissolved in water', and W. Kaye, J. Stewart and R. Paulson of Beckman Instruments ('Standard and test methods in spectrophotometry') described their company's efforts to improve on existing techniques.

Finally I should add, on a non-technical note, that we were well entertained, with an opening 'get-together' evening on the Monday, an evening of Hungarian music and dancing on the Tuesday, a conference banquet (at which Professor Striker spoke fluently in four languages other than his own) on Wednesday, and an official reception on the Friday by the Minister of Metallurgy and Machine Industry. It should also be recorded that the quality of the food and wine was very high indeed, everywhere I went. My memories of Budapest will be many: the heat, of course, rather obtruded, but also and particularly striking were the beauty of many parts of the city, the absence of a traffic problem, the extreme cleanliness of the streets and the parks (there is no litter to be seen anywhere) and, most of all, the desire of the people to be helpful although it was not always possible for them to do all they would have liked to do.

The recent U.S.S.R. industrial exhibition at Earls Court provided rather more of interest than was expected, particularly in the field of analytical instruments

Instruments at the Soviet Exhibition

by **REGINALD MEDLOCK,** *George Kent Ltd*

AN INDUSTRIAL EXHIBITION OF THE TYPE STAGED AT Earls Court displays such a wide range of products that it can scarcely be expected to include a large and varied selection of instruments. This was certainly true for the recent British Trade Fair in Moscow where the range of instruments exhibited was very limited indeed. For this reason the visit to Earls Court was made with more hope than expectation, and with this mental fortification against disillusionment, the day was well spent.

Of major interest was a wide range of analytical instruments shown in the Chemistry Section, which suggested that some concentration on development of this type of equipment had taken place in Russia, as a necessary link in the full automation of factories. In the Science Hall a section was devoted to automatic control equipment of a fairly advanced type.

The tortuous route given in the Exhibition brochure was followed in the hope that nothing would be missed. The following was the day's ' bag '.

Recording instruments

Three types of single-point electronic self-balancing recorders were seen, two with strip charts 6in and 11in wide respectively, and a third with a standard size circular chart. As far as could be judged, these instruments were conventional in design. Although not shown, multi-point versions of the 11in chart model are known to be available with up to 24 points. These instruments were not primary exhibits but were associated with measuring equipment for vapour-phase chromatography and other electrical and analytical measurements. It was disappointing that the miniature electrical recorders and transducers for flow, pressure and temperature were not shown, although these are now made and were seen recently at the Permanent Exhibition of Economic Achievement in Moscow.

Analytical instruments

In the Section devoted to chemistry, there was an interesting range of analytical measuring instruments of sufficient merit to be mentioned individually.

a A photo-electric type of liquid analyser, a specific application being the measurement of Cu^{++} in ammonia solution in the range 10 to 20 g/l. Operation is by the conventional principle of ' chopping ' light from a single source into two beams, one passing through a measuring cell and the other through a reference cell. Any unbalance between the amount of light passing through the two cells is used to drive a feedback system, which varies the area of the light beam falling on the reference cell. The output is taken from a potentiometer mechanically connected to the feedback system. Claimed accuracy is $\pm 10\%$ of full scale, and instrument dead time 1min.

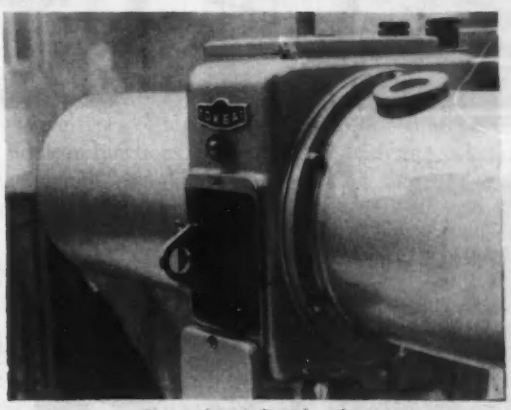


Photo-electric liquid analyser

b An infra-red gas analyser of the absorption type with a range of 0 to 0·05% carbon monoxide. The analyser and recorder are combined, which enables a null-balance system to be used consisting of a balancing

motor moving a vane in the infra-red beam passing through the reference cell. The detector is a conventional condenser microphone. The accuracy claimed for most applications is ±5% of full scale, and dead time not exceeding 40s.

c A radio-active liquid analyser which can be used for density measurements, a typical example being the analysis of a binary mixture of alcohol and water in the range 65–85% A differential measuring system is used, with two emitters, of yttrium 90 and strontium 90, for the measuring and reference channels The instrument automatically checks its own zero every six hours. Minimum scale range when used for density measurement is 0·01g/cm³, and claimed accuracy is ±5% of full scale.

d A photo-colorimetric instrument for measuring hydrogen sulphide, utilizing the lead–acetate impregnated-tape principle, the range being 0 to 100 parts per million of hydrogen sulphide. The change in colour of the tape is measured by the light reflected from it, this being compared with a reference. Claimed accuracy is ±10% of full scale, and instrument dead time 3min.

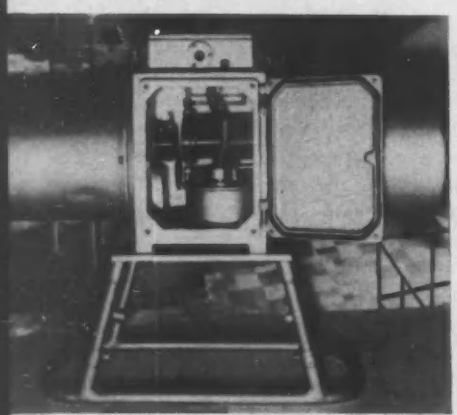
e A gas analyser for various ranges from 0–5% to 0–50% oxygen by volume. Although based on the well-known magnetic principle, this instrument uses a novel measuring cell in which the magnetic forces acting on the oxygen unbalance a gas bridge, in which only pure nitrogen is flowing. The special feature of this instrument is that it is insensitive to the specific heat/viscosity ratio of the gas being analysed. It has the further advantage that by substituting a standardized nitrogen/oxygen mixture for pure nitrogen, suppressed-zero instruments are possible without gross errors arising from barometric effects. The main disadvantages of the system are the need for purge gas and the possible effect of convection errors arising from any small temperature differences in the gas-bridge network. Claimed accuracy is ±5% and dead time 25s*.

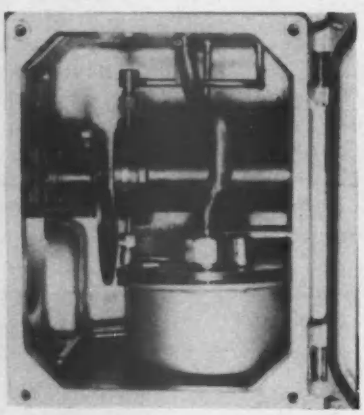
f An automatic gas and vapour alarm which is operated on the hot-wire principle.

g An electrochemical gas analyser. This employs the coulometric principle whereby a feedback amplifier supplies a direct current for producing the required amount of reagent by electrolysis. Two versions are made, having ranges of 0 to 0·01% and 0 to 0·5% sulphur dioxide respectively. The sulphur dioxide reacts with iodine produced by the electrolysis of potassium iodide. The claimed accuracy is ±5% of full scale, and the dead time 6min or 1min depending on the range.

h A sulphur dioxide analyser for sulphuric acid manufacture. This is based on the principle of thermal conductivity measurement, and is available in the ranges

* The principle of this analyser is more fully described on pages 93–94 of this issue.

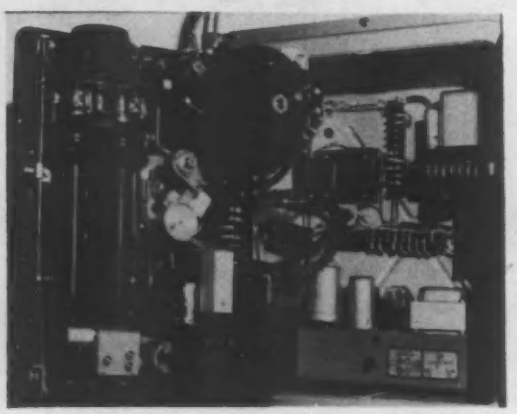


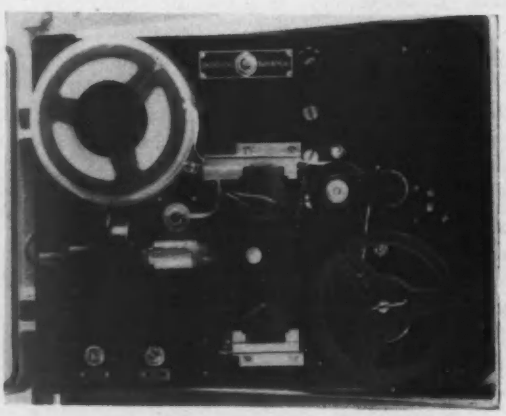


Left: two views of the radio-active liquid analyser. Density is measured by means of β-ray absorption: the composition of binary mixtures may thus be determined

Below left: combined infra-red gas analyser and recorder; measuring and reference cells can be seen on the left-hand side of the picture

Below right: Photo-colorimetric measuring system for hydrogen sulphide



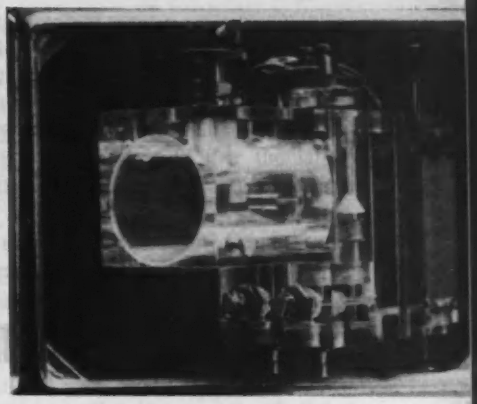


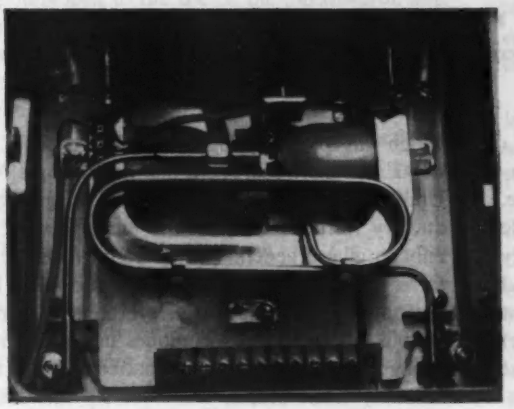
Top left: electrochemical gas analyser employing coulometric principle

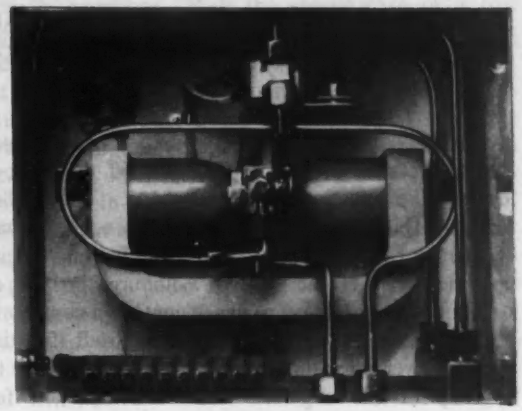
Top right: depolarization gas analyser, for measuring up to 2% oxygen in various gases

Bottom left: oxygen analyser with suppressed range. This is the instrument with the conventional type of measuring cell turned through 90°, so that the convection and magnetic effects are in opposition

Bottom right: new type of oxygen analyser, intended for applications where carrier gas composition varies widely







0 to 10% and 0 to 15% sulphur dioxide. Claimed accuracy is ±2% of full scale, and dead time 30s.

i A depolarization gas analyser for oxygen. The oxygen in the gas depolarizes a gold electrode which alters its potential. This change is detected by an amplifier which feeds back a direct current to re-establish cathodic polarization. This instrument is made for ranges between 0 to 0·1% and 0 to 2% of oxygen in various gases. Instrument dead time is stated to be 20s, and the accuracy ±5% of full scale.

j A magnetic oxygen analyser with suppressed range. A conventional type of analyser is used with the annular cell turned through 90°, thus balancing the convection effect against the magnetic effect. This permits the following ranges of oxygen to be measured: 20% to 60%; 20% to 80%; 50% to 100%; 80% to 100%; 90% to 100%; 95% to 100%. Claimed accuracy is ±5% and dead time 25s.

k A thermo-chemical gas analyser. Small percentages of hydrogen in oxygen or oxygen in hydrogen are measured by reacting the components catalytically and measuring the resulting temperature rise. Typical ranges are: 0 to 2% hydrogen in oxygen and 0 to 1% oxygen in hydrogen; 0 to 0·5% oxygen in producer gas. A dead time of only 15s is claimed, and an accuracy of ±5% of full scale reading.

Automatic control and automation

In the Science Hall, a section was devoted to the work of the Institute for Automation and Remote Control of the U.S.S.R. Academy of Sciences. A number of interesting pieces of equipment were exhibited, including, the following.

a Pneumatic switching and storage circuits as elements of pneumatic computer units. One demonstration consisted of a pneumatic computer for playing the game of ' morra '.

b Three types of logic machines, one for minimization of Boolean functions, the second for analysing switching circuits and the third for inspecting the quality of electrical and radio engineering products.

c Several optimizing controllers; one for single-channel work and two others for optimizing up to a maximum of eleven parameters.

Miscellaneous

For the oil field engineer, there was a range of deep-well instruments including a piezograph, a differential-pressure recorder and an inferential type flowmeter; for the refinery chemist, a chroma-thermograph, an automatic distillation apparatus, equipment for the determination of bromine number, and vapour-phase chromatograph equipment.

Engineers outnumbered mathematicians by two to one at Hatfield Technical College's school on the mathematics of automatic control

Summer-school mathematics for control engineers

by **H. GRAHAM FLEGG** M.A., D.C.Ae., F.R.Met.S.
R.A.F. Technical College, Henlow

HATFIELD COLLEGE OF TECHNOLOGY STANDS ON A ninety-acre site of rising ground just off the A1 overlooking the junction with the A405. The College, formerly Hatfield Technical College, is a fine example of post-war utilitarian architecture. It was officially opened by H.R.H. the Duke of Edinburgh in 1952, and after some nine years of existence now has a complement of approximately one hundred teaching staff (full time) and well over three thousand students. It was here that a group of 123 engineers and mathematicians foregathered on Monday, 26 June, to attend a one-week's summer school on the mathematics of automatic control organized by the Department of Mathematics.

The intention of the summer school was: 'To enable mathematicians and engineers working on problems of automatic control to study some of the relevant mathematical techniques developed in recent years in Britain, America and Russia.' Notwithstanding the primarily mathematical nature of the school, obvious both from the stated intention and from the lecture titles, engineers were present in a majority slightly greater than two-to-one. This is very much a sign of the present times, in which engineers in their quest for greater accuracy, with a consequent complication of equipment, have been forced to have recourse to branches of mathematics formerly the exclusive playground of the pure mathematician. Significant also, perhaps, was the refusal of over one eighth of those present to comply with a request to specify whether they were in fact primarily mathematicians or engineers. This might be taken to suggest that there is now a significant body of persons who feel that it is no longer valid to entertain such generalized classifications.

A vast canvas

The assembled company was first welcomed by the Principal of the College, Dr W. A. J. Chapman, who immediately set the friendly and informal atmosphere which was to last throughout the week. Mr J. F. Coales, O.B.E., of the Department of Engineering at Cambridge University, had the unenviable task of giving the introductory lecture, of which the aim appeared to be not only to give a general survey of most of the principles to be treated in detail later during the week, but also to attempt some sort of outline synthesis showing how the various mathematical techniques used in control engineering research fell into a pattern, some developing naturally from others, some merely alternatives.

Mr Coales began with a short review of the theory of linear systems and stressed the importance of Fourier transform methods. He then considered factors involved when high performance standards are demanded, in particular the complication of noise, which leads, since it is defined in terms of an autocorrelation function, to a study of stochastic processes. The mean-square-error as a criterion of performance was particularly commended . . . . 'it cannot be defaulted for linear systems'. Some comment was made about undesirable results which were obtained when design was directed exclusively towards discovering an optimum filter without consideration of the difference between a filter as such and a physical control system. A further complication discussed was that of including a digital unit within a control loop, thus involving a study of z-transforms and modified z-transforms.

Mr Coales went on to consider the effect of relaxing the criterion of linearity, with its immediate consequence that the law of superposition no longer applies. A far wider range of mathematical techniques is now required. Much mention was made of phase-space representation, which is responsible for much of the terminology of non-linear control theory. With the hourglass now fully exhausted, the listeners were led with apology through brief references to the methods of statistical mechanics, the use of orthogonal functions, and integral equations. The time appointed for morning

coffee having passed, would-be questioners were discouraged. It was sufficient for the moment that the broad outlines of the canvas had been painted; but what a vast canvas it was! Clearly there would be time in the days ahead to examine its detail more closely; equally clearly some of that detail at least would be completely new to many of those present.

Time series and z-transforms

The remainder of the first morning was devoted to a lecture by Dr A. J. O. Cruickshank of St Andrews University upon time series and z-transform methods. Sampling processes were considered from two points of view: first as resulting from the periodic closure of a switch, and then as processes of impulse modulation. Both viewpoints lead to the use of the z-transform, and it was easily demonstrated that the essential output/input relation governing the z-transforms for a filter with sample input is $W(z) = Y(z)/X(z)$, where $W(z)$ is the pulse transfer function of the filter, and $Y(z)$ and $X(z)$ are the z-transformed output and input respectively. $Y(z)$ gives the output at sampling instants only, and a modified transform must be used when it is required to find the output at all instants of time.

The sampled-data system shown in Fig. 1 was examined in some detail with $Q_0(s)$ a zero-order hold having a transfer function $(1 - z^{-1})/s$, with $G(s)$ equal to $b/s(s + a)$, and with the input $x(t)$ a unit-step function. Responses for a number of values of aT were calculated: T denoting the interval between impulses. The results

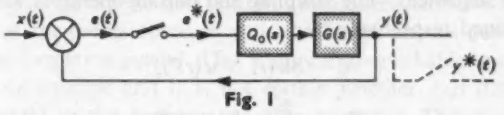


Fig. 1

indicated that the more oscillatory responses were obtained when sampling at the lower rates, and that if this was carried too far instability would ensue. The modified z-transform was then used to obtain the response of the same system between sampling instants.

Dr Cruickshank's next topic was the approximate transient analysis of continuous systems; the idea being to replace a simple transform equation $Y(s) = G(s)X(s)$ with a corresponding z-transform equation $Y_a(z) = A(z)X(z)$. In this latter relation $X(z)$ represents input information given by ordinates x_n only at the instants $t = nT$, and the function $Y_a(t)$ ultimately resulting is an approximate output. The model for this is identical in structure with that of a true sampled system. $A(z)$ has the form $Z\{Q(s)G(s)\}$ where $Q(s)$ functions as an interpolator. Three particularly interesting cases are those representing zero-order hold, polygonal approximation, and parabolic approximation. It was also demonstrated that z-transform methods can be used to obtain a time series solution of linear differential equations with constant coefficients.

The speaker then went on to explain how z-transform linear interpolation operators could be used for the solution of non-linear differential equations, and in particular of those representing control systems containing one non-linear element. The method demonstrated was that of A. Tustin, slightly modified. In the particular example chosen it was possible to solve the resulting equations reasonably accurately without recourse to graphical methods, but it was stressed that the latter will suffice to meet the normal demands of engineering accuracy.

The remainder of the lecture was devoted to approximate time-domain optimization for random inputs when instantaneous non-linear elements are included. Two approaches may be adopted: either one can work from first principles and replace the time functions by jump-function approximations, or one can replace the Wiener–Hopf integral equation by a set of linear algebraic equations. Both the simple case of a free configuration and also the open-loop and feedback cases of a semi-free configuration were discussed.

It was clear from the substance of Dr Cruickshank's lecture and the subsequent discussion that there are advantages in the time-series methods which are not possessed by other analytical procedures. For transient solutions, both linear and non-linear systems of any order may be analysed and the effects of varying particular parameters easily obtained. Few restrictions apply to the non-linear element, and a solution can still be obtained if more than one such element is present. Time-series methods are particularly appropriate for stochastic inputs and may be applied also to sampled-data systems.

Liapunov's methods

The afternoon of the first day was devoted to two lectures on the work of A. N. Liapunov, whose name gave rise to an immediate disagreement in pronunciation between the chairman of the day and the lecturers concerned, as had the spelling also differed by a 'u' in the printed program and the lecturers' own titles. The order in which the speakers presented their material was somewhat unfortunate. Dr Cartwright, Mistress of Girton College, Cambridge, spoke first and dealt with the question of deriving the stability properties of a system of equations directly from the equations by means of a Liapunov function. Dr Cartwright clearly assumed that her audience were fully aware of, or would immediately appreciate, the connexion between Liapunov's methods and the conception of phase space, a point which was not made explicitly until the question period at the end. It was apparent from subsequent discussion that not all present had had this in mind during her lecture, and Mr P. C. Parks, of Southampton University, who followed, was asked to begin his allotted hour with a simple introduction to the phase space concept, a definition of stability in the sense of Liapunov, and an explanation of the significance of the descriptions 'positive-definite', 'negative-definite', 'positive semi-definite', etc. Having complied very kindly with this request, Mr Parks then discussed the first and second

methods of Liapunov. The first method is usually associated with a set of a particular type of differential equations and provides a proper theoretical basis for extending the conclusions drawn from consideration of the effect of small disturbances on the linearized equations to conclusions concerning the stability of the original full equations. Certain critical cases which have received particular attention from Russian authors were mentioned.

The proof of Liapunov's first method depends upon the second method, which involves a search for positive-definite functions, $V(t, x_1, x_2, \ldots, x_n)$, whose derivatives V', given by

$$V' = \frac{\partial V}{\partial t} + \sum_{i=1}^{n} \frac{\partial V}{\partial x_i} X_i (t, x_1, x_2, \ldots, x_n),$$

are negative-definite. The natures of the function V and its derivative indicate the stability of the solution $x_i = 0$ of a set of equations

$$\frac{dx_i}{dt} = X_i (t, x_1, x_2, \ldots, x_n).$$

The remainder of the lecture was devoted to considering a number of specific examples illustrating the use of Liapunov's second method. These included Lagrange's theorem on stability, a bang-bang roll-control system, the stability of a rotating projectile, and the stability of a missile oscillating in roll.

In practice, it is necessary to know whether there is any limit on the extent of disturbances to which a system may be subjected and yet still return to its equilibrium position. This can be investigated by examining the region in which Liapunov functions and their derivatives following the trajectories in phase space remain sign-definite. Having dealt in outline with a special case due to L. P. LaSalle, and with the case of estimating the rate of decay of a stable transient motion, the lecturer concluded with some very pertinent remarks relating to the mathematical content of university engineering courses in the west. These courses were considered to be most inadequate in the light of recent developments in the various fields of research. There is little doubt that Mr Parks was right to point out that the shortage of able mathematics teachers with a real insight into modern engineering methods is a matter which should be giving rise to much greater and more immediate direct action at the highest levels in this country.

Variational methods

The second day of the summer school began with a talk on 'Variational Methods' by Mr M. J. McCann of Imperial College, who was formerly a Hatfield student. The expressed aim was a detailed comparison between the use of the classical calculus of variations and the methods of L. S. Pontryagin for determining the optimum control adjustments of a given system or plant on the basis of some criterion such as maximum economic return or least deviation from a stated product quality. The material was presented without proof and was directed almost entirely to demonstrating the appropriate transformations which link the two methods. Mr McCann seemed a little undecided as to the optimum platform manner for the occasion, and his attitude varied from the jocular—glossing over his failure to justify many of his assumptions—to blunt statements of a 'like it or lump it' variety. His enthusiasm cannot however be doubted, since he offered his audience a bonus in the form of a subsidiary and unprogrammed lecture on dynamic programming, the omission of which he considered a serious defect of the course. After a rather unsuccessful attempt to satisfy questioners who were demanding a more rigorous justification for some of his material, the offered bonus had to be declined, and the company dispersed for coffee.

Operators

The next subject to be considered was an approach to the analysis of linear sampling systems, using operators as an alternative to z-transform methods. This was presented by Professor B. M. Brown of the Royal Naval College, Greenwich. Starting from the familiar operator D applied to functions of time, Professor Brown demonstrated how the standard difference operators E, Δ and ∇, as applied to sequences, together with a sampling operator S and a pulsing operator P, could be combined with functions of D to define systems which include some signals that are functions and some that are sequences. The sampling and pulsing operators were defined respectively by

$$u_r = \mathrm{S}u(t) = u(rT),$$

$$\mathrm{P}u_r = \sum_{r=-\infty}^{\infty} u_r \, \delta(t - rT).$$

A clamping operator, C, was then introduced to define the function which takes the value u_r when $rT < t < (r + 1)T$. This function is written as $\mathrm{C}u_r$, where

$$\mathrm{C} = \nabla \, \mathrm{D}^{-1}\mathrm{P}.$$

The process of clamping is, of course, the same process as that performed by a zero-order hold.

Some time was then spent on the manipulation of operators to show that rational functions of E are freely commutative with S, P and functions of D. An operational representation of delayed sampling, which gives the response of a system at and between sampling instants, was also demonstrated. Professor Brown concluded with a plea that operational notation should be used much more extensively than it is at present. One of the principal advantages claimed was the clear distinction gained between the signals, whether functions or sequences, and the elements or transducers in the system being represented. However, there were at least some people who appeared to remain unconvinced of the value of changing present practice for an approach which is confined to systems which are basically linear.

To be continued

PART 2

More useful information from the I.E.E. international conference, selectively reviewed for control engineers

Components and materials in electronic engineering

by **G. L. ASHDOWN** I.C.M.E. (Brussels), M.I.E.E., F.Inst.P.

Battersea College of Technology

Electrolytic capacitors

Four papers were presented in a session devoted to electrolytic capacitors. In one of these (Franklyn) development over the last twenty years was reviewed. Details of construction were given and layer growth and break-down phenomena were discussed. In the case of the latter a new term was introduced, *subscintillation*, for events observed with aluminium anodes during the formation period. This is only distinguishable under a microscope and it is not certain whether it is detrimental to the performance of a capacitor. The choice of electrolyte was discussed in this paper, which is a useful one for manufacturers of electrolytic capacitors.

The effect of frequency and temperature upon tantalum capacitors was fully discussed in another paper (Mead). Foil, wet pellet and solid types were considered, and impedance and loss angles were measured between −40 and +100°C over the range 50 c/s to 100 kc/s. The results were compared by determining the ratio of the impedance at the frequency of measurement to the nominal reactance of the capacitor. The interesting conclusion was reached that at low temperatures the impedance of a paper capacitor of much lower nominal capacitance can be lower at frequencies above 1 kc/s than that of a tantalum capacitor. This is particularly noticeable with the foil type. It was suggested that 1 kc/s is a more useful test frequency than 50 c/s.

The third paper (Smith) was concerned with reliability of tantalum foil capacitors. The criterion chosen was that the capacitance dielectric loss should not exceed 50%. A subsidiary requirement, that the dielectric loss should not increase by more than ten times, was found to be unnecessary. A time to failure was defined under these conditions as it was found that when a large number of capacitors was tested no failures were obtained up to a definite number of hours, and thereafter the number of failures increased linearly with time. It was concluded that the time to failure of the foil-type tantalum capacitor can be determined entirely in terms of the change of capacitance during operation. The life is, of course, dependent on both temperature and voltage, and an empirical law relating life to these two quantities has been determined. Useful life depends approximately on the fifth power of the applied voltage and decreases by a factor of between 1·4 and 2·4 for every 10degC increase in operating temperature. The figures for life are considerably higher for low-voltage capacitors. In the last paper (Vincent), on the performance of aluminium capacitors under pulse and high-frequency conditions, it was pointed out that the important characteristic of the capacitors for this use is low series resistance. Some indications were given of the performance of capacitors specially designed for this purpose. It was considered too early to give any reliable figures regarding life, but it would appear that under computer conditions 10,000 hours can be expected.

Design and test

Five papers were concerned with choice of materials, design and performance of plugs and sockets, and selection of relay contacts, but the discussion centred very largely around methods of testing, and, as with resistors, reliability. It was pointed out that film which might not be broken down by the small telecommunication current must not be destroyed during the test. In many cases, the failures due to the formation of non-conducting or poorly conducting films are overcome in

CORRECTION: On p. 109 of last month's issue the reference to the use of twin elements to overcome misalignment refers to thin-film magnetic elements and not to the special synchro mentioned in the preceding paragraph.

practice by the use of a sufficiently high wetting voltage, e.g. 50V, with or without high pressure. One contributor pointed out that wiping the contact is not always satisfactory as the non-conducting film can be scraped into a small pile on which the contact then rests, thus making matters worse than if direct pressure had been used. A test figure of 10 mV was recommended.

An interesting design of connector for printed-circuit boards in which the contacts are cam-operated so as to avoid excessive rubbing of the printed-circuit connexions was presented (Myatt). A small wiping action (approximately 0·001in) takes place, but the wear on the printed-circuit plate is considerably reduced by this type of socket.

The two materials most commonly used for the surface of contacts are gold and palladium, and for these two the recommended forces are 30gf and 10gf respectively. Both these materials are reasonably free from corrosion, though in certain cases contact corrosion has been traced to the insulating material on which the contacts are mounted. It was also considered undesirable to use silver under these two materials, as there was eventually diffusion of the silver through the gold or palladium. One opinion expressed was that gold could be used where reliability is of prime importance, and palladium, which is cheaper, but with a performance that is less well known, where cost must be considered.

It was suggested that too much emphasis is placed on a large number of operations for plugs and sockets, and that a figure of 500 would be adequate for most requirements. This does not, of course, apply to relays, and some figures were given for life test of a sealed relay operating at 10V with a current between 10 and 20 mA. This failed after ten million operations owing to the formation of hills and craters on the silver contacts, causing welding.

Micro-miniaturization

Two papers in the session on micro-miniaturization presented the state of the art in the United States (Franklin) and gave a review of Government-sponsored work in the United Kingdom (Granville). The American paper consisted essentially of examples of miniature circuits, whereas the British paper dealt in more detail with the various types of element produced in this country, and included a valuable survey of the different aspects of the problems being treated by Government establishments, by various research departments, and by manufacturing concerns. The advantages and disadvantages of micro-miniaturization (micro-modules, micro-circuits and solid circuits) were also given in the British paper.

The discussion centred very largely on design and maintenance of systems involving miniature components. Few of the opinions expressed could, of course, have been based on actual experience, and it will be interesting to see in subsequent years which of the two following lines of thought are correct from the design point of view. There were as many contributors who thought that component manufacturers would cease to exist owing to the manufacture of complete circuits as there were who thought that system designers would have no work to do. The component manufacturers could not see how their work would not be extended to include circuit design, and the system designers were reluctant to release the responsibility of circuit design to the component manufacturers.

As regards maintenance, and also modifications of circuits during experimental periods, some contributors doubted whether it would be possible to produce a new complete element quickly enough. Others thought it would be too costly but the designers of this type of equipment pointed out that there was very little more work in producing the complete circuit with printed or evaporated wiring than in producing a single transistor, it being argued that the major cost of the production of transistors is the connexion of the leads. This discussion gave plenty of scope for crystal-gazing, and the only tangible evidence from this session was that a lot of development is going on and that the various types of micro-miniature equipment will eventually reach the systems designer whether he likes it or not.

From the point of view of technical difficulty, the most discussed aspects were heat dissipation and interconnexion. Connexion cross-overs can have capacitance values of 10 pF or more and although this is possibly satisfactory for digital work up to 100 kc/s it would be prohibitive for higher speeds.

One interesting comment, which related this session to the preceding one, concerned the method of making joints onto thin films. According to the contributor, he had never been able to make a dry soldered joint on a thin film, and therefore saw no reason to adopt any other method of connexion. He attributed this to the fact that the material of the film is pure and clean. Regarding the elements of micro-circuits, information was given on a tantalum resistor which after aging at 150°C maintained its value to with 0·1% per thousand hours. The temperature coefficient is high at a hundred parts per million per degC, but the value of the material is that it can be anodized, and this surface prevents electrolytic action, and the anodic coating, being an insulator, can be used to adjust the value.

Inductors, magnetic materials, and transformers

A session was devoted to inductors, magnetic materials, and transformers, and nine papers were presented. After a summary of the numerous properties of magnetic materials and their method of presentation (hysteresis loop, permeability, frequency effects, etc.) the need for information relating to the application was stressed. Two papers dealt with special methods of testing to meet specific requirements; peaking transformers (Langley Morris) and magnetic amplifiers (Attenburrow and Jasko). For both applications the same properties are required, but the latter demands the performance of matched cores over a wide range of flux. Only four

points are required to satisfy magnetic amplifier design requirements.

In the paper on relays (Fairweather, Hands, Lazenby and Marr), the effect of the preparation of the materials on the subsequent life of the relay received detailed examination. Even materials in the oven during annealing can have a very marked effect on a life. Nitrogen was considered the least desirable atmosphere, and the presence of a silicon furnace tube was said also to affect performance adversely and should be avoided. It was noted in the discussion that cracked ammonia is not a good substitute for hydrogen as it produces severe aging which puts relays out of service in two years.

The discussion was largely concerned with confirming many of the points in the papers. The question of performance at high frequencies was raised by one speaker, who suggested a more complete equivalent circuit. This circuit included the capacitance and resistance of the electrolyte as well as the capacitance of the oxide film. He claimed that this circuit gave a better approximation to the variation of impedance with frequency when the equivalent resistance of the electrolyte was high. One contributor suggested that the measurement of impedance was a good measure of aging. This claim was based on performance over 500 hours. For tantalum capacitors a table was also given for temperatures ranging from 20°C to 85°C and p.d.s. from 100 to 150V. The capacitors tested were rated at 50°C and 150V. The life ranged from 1400 h at the highest voltage and the highest temperature to more than 100,000 h at the lowest voltage and room temperature. Similar results had been obtained in Sweden for capacitors rated at 40V, the life being 8000 h at 70°C and over 100,000 h at 40°C. The remainder of the discussion was devoted largely to design details and choice of materials.

Printing and potting

Eight papers were presented in a session dealing with printed wiring and potted circuit techniques and methods of connexion. A review of trends in potted and printed circuit techniques (Manfield) gave the characteristics and performance of various materials and three complementary papers (Davies; Davis, Rees and Riley; Powell and Stolton) dealt with encapsulating materials. Two further papers dealt more specifically with printed wiring and circuits (Sweet) and laminates (Knewstubb). These papers together gave very comprehensive information on the materials used in this technique. The effect of epoxide resins on the reliability of components (Fletcher) would appear to be almost all mechanical; chemical attack is negligible.

The remaining paper (Butterworth) dealt with wrapped solderless joints and formed the basis for much argument during the discussion. The author claimed that wrapped connexions were more reliable than soldered joints and in spite of numerous examples during the discussion (e.g. crimped connexions in aircraft) there were still some contributors who doubted whether the wrapped joints would be satisfactory in industrial atmospheres. It would appear that tests at Bell Laboratories had predicted a life of forty years for wrapped joints, the tests having been on 10,000 joints in ground equipment and 1200 joints in missiles.

Reliability

Six papers were concerned with reliability and included mechanics of failure, the validity of accelerated life tests and results. One of the papers (Fairweather, Lazenby and Parker) dealt with contacts with particular reference to adverse environmental conditions. The authors examined various coatings and concluded that they were frequently inadequate. These included the noble metals, and it was stressed that much more stringent quality control was required. It was claimed that dry transfer lubrication for switch contact can increase life at least three-fold.

Regarding test procedure, it was suggested by a contributor from Sweden that bad contact resistance could be detected by determining the harmonics in the voltage across the component when fed with a pure sine-wave of current. In the actual equipment the third harmonic was amplified and displayed. The sensitivity is such that an attenuation of 160dB is obtained between fundamental and third harmonic. It was found that by this method the rogues mentioned in a previous discussion could be sorted out, and that good agreement with the measurement of noise was obtained, the method being more sensitive and easy to use.

Manufacturers were criticized for not giving enough information on the life and reliability of their components. They replied that accumulation of data was very largely in the hands of the users, and that any tests carried out by the manufacturers could only be artificial and might not be related to any particular application. One manufacturer pleaded for users to send back any faulty components with details of their performance and operating conditions. Only by this means could they correlate their tests with actual performance. The usefulness of a failure rate was criticized by one speaker. Even if one has enough time to obtain a good figure, failure from batch to batch was bound to vary. He suggested that, while one should still carry out life tests, it would be more valuable to publish details of what went wrong and then improve this particular failing. Not only would each user be able to determine the usefulness of the component for his particular use, but many more data would be accumulated on the cause of failure. One contributor was of the opinion that greater knowledge of the physical and chemical processes involved would be of as much value as the conditions of use, and another asked whether aging, of capacitors in particular, and some of the tests which were normally used, could not cause deterioration of the component. Was it not possible that the voltages used for testing could create incipient break-down? No detailed answer to this question was forthcoming. *End*

Pick-off

by 'UNCONTROLLED'

ACCORDING TO THE U.N. World Economic Survey for 1960, Britain had increased its volume of exports by 9% over the preceding three years. Belgium, Denmark, France, west Germany, Italy, Holland, Sweden and Switzerland all managed double-figure percentages, the lowest being 13% for Denmark and the highest 50% for Italy. 'This island can no longer rely upon the economic reliability of its established technical skills', said Lord Hailsham at the recent B.C.A.C. conference (see G. M. E. Williams' report of it on p. 68), and added: 'There is no hope whatever of our retaining competitive power against people with a lower standard of life who are already mastering many of the simpler techniques, and some of the more advanced ones too, of mass production. If we stand still we shall be successfully competed against, and beaten, in one field after another. We shall be priced successively out of the market in every case where lower wages, and equal or almost equal industrial skill, can be assembled and brought to bear.' Horrible thought, isn't it?—to be beaten not only by our peers on the Continent, but also by hitherto 'underdeveloped' countries. As Lord Hailsham so rightly inferred, 'automation is a necessity for our national future'. But what is the Government doing? Swiping indiscrimately at all investment in the country!

THERE WERE THREE of us—an engineer, his business-man employer, and myself—and we were looking at a histogram which recorded the company's ups and downs in a particular market. The business-man's forefinger moved along the column-tops and swept off the last of them in a gracefully ascending twirl. Later, the engineer and I were left to each other. Then I admitted that the mean curve through the histogram looked to *me* as if it had flattened out, and the rise at the end was a local one from which *I* should have thought it unwise to extrapolate. The engineer agreed, rather sadly, and made some shrugging remark about 'business types'. Of course, engineers just have to be honest with themselves, and they learn very early how to read graphs properly. But there may be a deeper moral here. I agree that engineers have in the past been too preoccupied with steady-state design and have sometimes avoided consideration of transient conditions (after all, they *are* more difficult), but that is not the point I am thinking of in this case. Business-men flourish by their trick of watching the transient variations and trying to keep themselves in the positive areas for longer than they are in the negative ones, and it is entirely natural for them to see the corrugation of a surface rather than its general shape. While this makes for bumpy riding, there are always the lucky ones who take off. Their success doesn't come from superior knowledge—I still back the engineer's reading of that histogram—but it makes them very hard to argue with. Maybe the shrug is the best answer after all.

ELSEWHERE in this issue there is an account of certain American machine tools that are to be produced over here for the Commonwealth and European markets. When this was announced at a press conference last month I was glad to hear the machine tool people give due credit to Ferranti's for bringing prices to a commercially interesting level. The cost of the control equipment is now down to a third or a quarter of the whole. As Peter Tripp remarked at the conference, this means that the machine tool is no longer an ancillary of the control system. It is good to see that some members of Britain's moribund machine tool industry are showing signs of life—perhaps their example may stir the others up a bit.

NOT EVERY HERO is a Montgomery, and the British variety usually prides itself on dodging the limelight. But lionizers will have their way whatever their idols may suffer, and a sympathetic third party usually understands the feelings on both sides. However sympathetic the third party, though, he probably likes to see the suffering fairly shared. I was among those who felt rather uncomfortable about the reception given to Major Yuri Gagarin recently. Not that *he* didn't deserve the adulation he endured—I just wondered whether anybody would have noticed a visit by Messrs Eckskoff, Wyeski and Zedvitch, the *technical* people behind the Soviet rockets.

OUR CZECH CONTEMPORARY, *Automatizace*, has done us the honour of reviewing *Control* in its May issue. Ing. Vladimír Kotěšovec, the editor, has very kindly provided us with a translation of this gratifying piece. One of its concluding remarks struck us particularly, and led at least me to various philosophical reflexions. I shall quote just the last three sentences of the translation and leave you to your own thoughts: 'The journal is in its fourth year of publication, it has a very high level of graphical arrangement and is printed on chalk surfaced paper. Despite the great number of advertisements the contents are very attractive. We shall certainly be able to use it as a source of interesting news and reports.'

THERE WAS a great deal of public awe when the world's biggest computer was inaugurated in Washington by the President recently. A solemn assembly gathered in the temple-like building in which the machine is housed, and there was a profound hush when the President invited a young man on to the platform to put any question he liked to the computer. 'Is there a god?' asked the young man. 'There is now' answered the oracle.

Perhaps it is too easy to make jokes about computers.

A monthly review — under basic headings — of the latest control engineering developments for all industries; especially edited for busy technical management, plant and production engineers, chemical engineers, etc., who are interested in instruments and control systems.

IDEAS APPLIED . . .

. . . to ANALYSIS

Oxygen recorder insensitive to carrier gas composition

The 'magnetic wind' principle has established itself as a reliable method for determining the oxygen content of most gas mixtures. The design of analyser commonly used, however, has the disadvantage that its readings are to some extent dependent on the physical characteristics of the carrier gas. The sensitivity of such analysers is proportional to the ratio of the specific heat C_p to the viscosity η of the gas mixture. If this ratio is subject to variations which cannot be allowed for in the analyser calibration, the readings of the conventional instrument will be inaccurate. In many applications this variation is small, or is known in advance and can be compensated for. (A typical case is the analysis of flue gas, in which the oxygen content virtually determines the proportions of the other constituents.) There remain, however, some chemical plant applications where C_p/η varies in a manner which cannot be taken into account during calibration. A Russian instrument shown at the recent exhibition in London has been designed for such applications. It is more complex than the conventional instrument, and requires a continuous supply of a 'reference' gas, but it measures the oxygen content by a method which is independent of the properties of the carrier gas.

For comparison, Fig. 1.1 shows a conventional oxygen analyser cell. The gas mixture enters at *A*, splits to take the alternative paths round the annulus, and leaves at *B*. In the absence of any external influence, there would be no flow through the central tube *E*, round which the heating coils *C* and *D* are wound.

The left-hand end of *E* is subjected to an intense magnetic field, which attracts oxygen-carrying gas from the

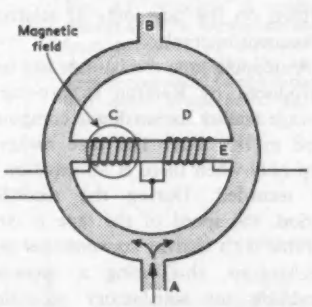


Fig. 1.1 Conventional magnetic oxygen analyser cell

left-hand limb of the annulus. This gas is heated by the coil *C*, and the increase in temperature decreases the magnetic susceptibility of the oxygen. More cool gas mixture is then attracted, displacing the heated gas. There is thus a continuous flow of gas from left to right along *E*, caused by the higher-susceptibility gas replacing that which has been heated. The flow causes a temperature difference, and consequent difference in electrical resistance, between *C* and *D*, more heat being removed from *C* than from *D*. *C* and *D* are connected into opposite arms of a bridge network from which the output is taken to the oxygen recorder.

The differential pressure established across the tube *E* by the magnetic/thermal effect described depends only on the oxygen concentration of the gas. The resulting flow through *E* is inversely proportional to the viscosity of the gas mixture. The temperature difference established between *C* and *D* is proportional to the rate of flow of the gas and to its specific heat, i.e. it depends on C_p/η.

The new Russian analyser uses a similar thermal detector to give the ultimate output, but it is arranged by means of further gas circuits that only a known reference gas passes through the detector. The principle is shown in Fig. 1.2. A supply of reference gas, such as nitrogen, passes through flow and pressure controllers (not shown in the diagram) before entering the gas-bridge at *F*. Here the gas stream splits, being taken through two equal restricting orifices R_1 and R_2 to two nozzles S_1 and S_2 exhausting into the the chamber *G*. The line to S_1 passes one pole of the magnet M_1, and discharges into the restricted space between

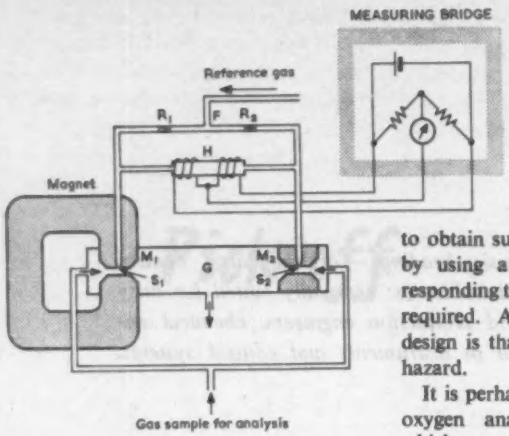


Fig. 1.2 Schematic diagram of new type of analyser. The magnetic effect on the sample gas in the neighbourhood of S_1 unbalances the gas-bridge formed by the restrictions R_1 and R_2 and the nozzles S_1 and S_2

the opposite poles. The arrangements for S_2 are similar, except that the 'poles' of M_2 are non-magnetic.

The sample of the gas mixture being analysed is split and taken to the two ends of the chamber G. The two streams pass the nozzles S_1 and S_2 respectively through the restricted passages, and are exhausted from G through a common exit.

If the gas sample in the neighbourhood of S_1 contains oxygen, it can only be displaced from the magnetic field by the reference gas if the latter is at a slightly higher pressure than would be necessary to displace an oxygen-free mixture. Thus the pressure in the S_1 line will exceed that in the S_2 line by an amount dependent on the oxygen content. Reference gas therefore flows through H, which is a thermal detector similar to that described above for the conventional analyser. As before, the gas flow causes a thermal unbalance which is used to obtain a reading of oxygen content from an electrical bridge network.

The complete analyser is housed in a temperature-controlled cabinet, control being effected by hot air with which the cabinet is continually purged.

The accuracy claimed for this equipment is 5% of full scale reading. Possible sources of error might be build-up occurring at the restricting orifices, and convection effects in the tubes connecting H and G, caused by small temperature differences. Differential pressures across H could arise from either of these causes, and might be large compared with the very small differentials caused by the magnetic effect.

The use of a reference gas, though in general a disadvantage of the system, suggests that it would be relatively easy to obtain suppressed-range instruments by using a gas of composition corresponding to the amount of suppression required. A further advantage of the design is that it is free from explosion hazard.

It is perhaps worth noting that other oxygen analysers have been made which are insensitive to the thermal characteristics of the carrier gas—e.g. the D.C.L. Servomex equipment. In this equipment, the magnetic forces acting on the oxygen exert a couple on a delicate suspended mechanism. This is retained in position by an electrical feedback current which also provides the output.

. . . to STORAGE

Magnetic tape store for analogue computers

In many analogue computer applications, it is desirable to store a result for use in a subsequent calculation. A possible means of storage is to convert the result to digital form and 'write' it on magnetic tape, from which it can be 'read' when required. This would be impractical with conventional tape transport mechanisms, where the tape moves continuously at high speed, as in this type of work information is written on the tape only at relatively infrequent intervals.

A stepping tape mechanism has been introduced by Redifon to provide a storage facility for analogue computers used in this way. The tape makes a step only when there is information to be recorded. During the recording period, the speed of the tape is comparable with that of conventional tape mechanisms, this being a necessary condition for satisfactory recording. A 35mm tape with sprocket holes is used, similar to cinematograph film. It is carried on two sprockets driven by separate stepping motors and gearing, so that writing and reading may be controlled independently (see Fig. 2.1). The slack tape between the two heads is taken up by a spring-loaded pulley.

Each step of the tape comprises a relatively short acceleration period, followed by a period of nearly constant velocity and a short deceleration period. Thus, to record, an 'advance' pulse is fed to the 'write' stepping motor and the analogue result is fed to an analogue-to-digital converter. The digital result is fed to the 'write' heads (sixteen heads may be accommodated across the 35mm tape), the timing being arranged so that writing takes place during the constant-velocity period of the tape motion. It will be noted from Fig. 2.1 that the operation of the take-up mechanism during the 'write' operation does not change the position of the tape relative to the 'read' head. The sequence of the 'read' operation is similar, the output normally being taken to a digital-to-analogue converter.

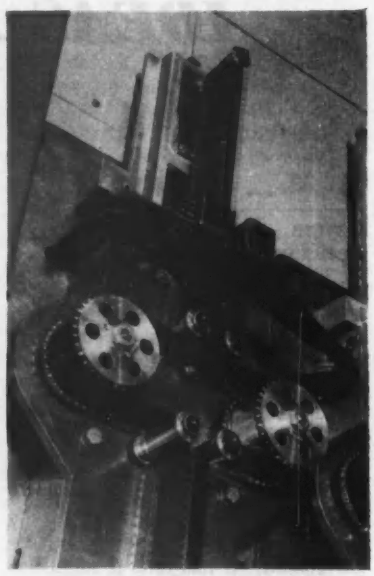


Fig. 2.1 Stepping tape mechanism

The principal object of this equipment is to give small analogue computers greater capacity and flexibility. An example of its application would be in 'finite difference' iterative processes, such as are often used to solve heat-transfer problems. In problems of this kind (e.g. the transfer of heat along a metallic conductor), the heat-path is arbitrarily divided into a number of small finite sections, each of which is subject to similar conditions. The analogue computer is set to simulate one section. The final values from the nth section are stored in the digital memory unit and used to reset the same integrators, which then compute the values for the $(n + 1)$th section. Redifon suggest that this approach could be

used for the analysis of multi-plate distillation columns.

A further suggested application for the memory unit is as a random 'noise' generator for use in analogue computer plant simulations. Random amplitude variations may be pre-programmed on one memory unit, and random time-pulses on a second memory unit which is then used to supply the 'advance' pulses to the first. The 'noise' so produced is then added to the function (sine-wave, ramp, etc.) which is to be used as the forcing function for the analogue simulation.

. . . to COMPUTATION

High-speed analogue multiplier

by D. L. A. BARBER, National Physical Laboratory

A number of cheap, reasonably accurate, high-speed analogue multipliers were required in connexion with adaptive control problems currently being studied in the Autonomics Division of the National Physical Laboratory. No suitable device being commercially available, a new circuit was developed which has a number of advantages over existing types of multiplier. The circuit uses transistors to produce a rectangular wave-form of amplitude proportional to one variable, and width proportional to a second variable. The product of the two variables is obtained by integrating this wave-form. The basic principle of the multiplier is shown in Fig. 3.1

One variable X is applied to a circuit which generates a pair of antiphase wave-forms with a mark/space ratio dependent upon the value of X. These wave-forms are fed to transistor switches which alternately open and close the connexions between earth and points A and B. The second variable Y is applied to points A and B through resistors R. Signals are produced at A and B with a mark/space ratio dependent on X and amplitude proportional to Y. One signal is inverted and added to the other, and the result is smoothed to form the output.

When X is zero, the mark/space ratio is made unity. The signals at A and B have equal amplitude and duration and the output is zero. Variation of X through zero changes the sign of the output and, since Y may be positive or negative, 'four-quadrant' multiplication is achieved.

Fig. 3.2 is a simplified diagram of the variable mark/space generator. Transistors T_1, T_2 form an emitter-coupled multi-vibrator, which generates anti-phase rectangular collector wave-forms with a mark/space ratio dependent upon the ratio of the emitter currents. The emitter currents of T_1, T_2 are varied by means of the 'long-tailed' pair formed by transistors T_3, T_4. The collector wave-forms of the multi-vibrator are amplified by T_5, T_6 to provide drive voltages for the output switching transistors. A feedback voltage, obtained by smoothing the wave-form at T_6 collector, is added to the input to linearize the mark/space variation with changes of X.

The existing multiplier accepts X and Y values in the range $\pm$100V and provides the product XY in the range $\pm$5V. A linearity of about $\frac{1}{2}$% is obtained with a band-width of 0–10 kc/s, and zero drift is about 10mV for a 25degC change in ambient temperature. A wide-band version of the multiplier is under development.

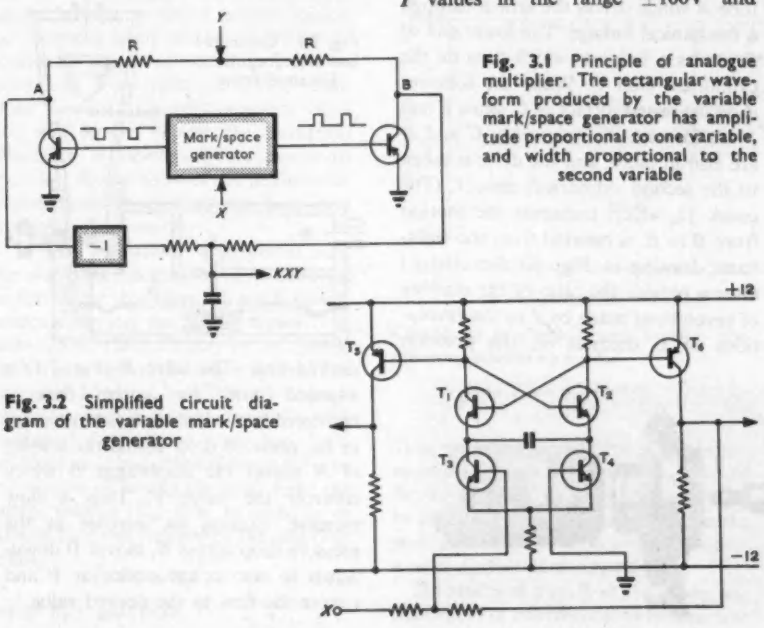


Fig. 3.1 Principle of analogue multiplier. The rectangular wave-form produced by the variable mark/space generator has amplitude proportional to one variable, and width proportional to the second variable

Fig. 3.2 Simplified circuit diagram of the variable mark/space generator

The above description is published by permission of the Director of the National Physical Laboratory. The work described is part of the research programme of the laboratory, and is the subject of a patent application.

. . . to ALARMS

Photo-electric device to fit existing instruments

A photo-electric warning system which may readily be fitted to existing indicators and recorders has been developed by Sealey Engineering. The detecting head, measuring approximately $\frac{3}{4}$in × $\frac{1}{4}$in × $\frac{3}{8}$in, may be fixed to the instrument glass, as shown in Fig. 4.1.

The head contains a light source, lens and photocell. It relies on the difference

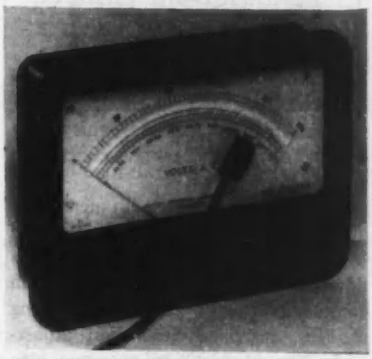


Fig. 4.1 Photo-electric alarm device attached to meter glass

in the intensity of light reflected from the instrument scale and from the pointer. The only prerequisites for satisfactory operation are thus a clear area of relatively bright scale and a relatively dark pointer—conditions which are fulfilled by almost all analogue indicating or recording devices.

. . . to FLOW

Meter with rotor outside main flow stream

A new type of rotary flowmeter, introduced by Rotron Controls (a member of the Elliott Group), is driven by a vortex of the metered fluid outside the main flow stream, instead of having a rotor mounted in the flow stream in the usual way. Little obstruction is presented

to flow, so that the meter is normally unaffected by suspended solids. A further advantage of this particular design is that its range can be changed very simply.

The rotor runs in a cylindrical chamber, offset from the main flow pipe as indicated in Fig. 5.1. A vortex of fluid is formed in this chamber, the angular velocity of which is linearly related to the velocity of the main stream. The rotor tends to rotate with the vortex, but with a certain amount of 'slip'. This slip is overcome by feeding some of the metered fluid axially into the rotor, *via* guide plates. The force exerted by this fluid moving radially outwards through the rotor blades maintains the speed of the rotor to correspond with that of the vortex. A magnetic coupling is used to transfer the drive from the pressurized part of the meter to the

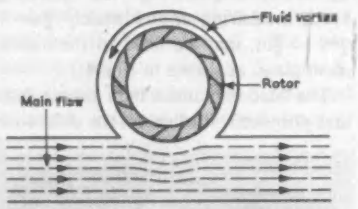


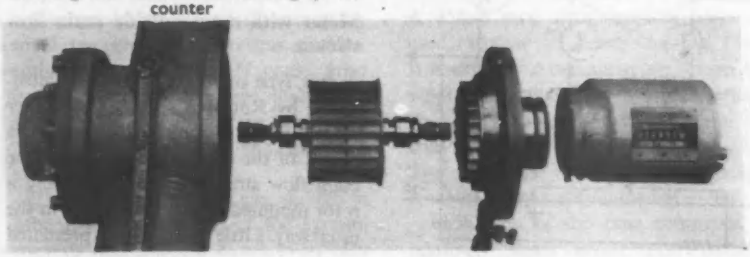
Fig. 5.1 Principle of vortex-operated flowmeter

required read-out devices, which may be local or remote, and give either total flow or rate of flow.

A channel inside the main meter tube allows a proportion of the flow to by-pass the vortex system. The by-pass flow may be varied by a baffle, which, in conjunction with external gearing changes, provides calibration adjustment. The adjustable by-pass may also be used for range adjustment in the field.

An accuracy of ±0·5% of the indicated reading is claimed for the Rotron flowmeter, with repeatability of ±0·1% of the indicated reading. It will normally cover a 10 : 1 flow range with the stated accuracy, though this depends to some extent on the density and viscosity of the metered fluid.

Fig. 5.2 Main component parts of Rotron meter. From left to right: vortex chamber, rotor, guide vanes and bearing plate, counter



Automatic pressure and temperature correction for gas meters

The recent increase in the applications of high-pressure gas has caused renewed interest in the question of automatic correction of the readings to standard conditions. For low-pressure applications, where corrections are often small, and where little power is available for driving correcting mechanisms, corrections are normally calculated. In high-pressure practice, these conditions do not apply, and Parkinson and Cowan are introducing in this country a correcting mechanism manufactured by the American Meter Company.

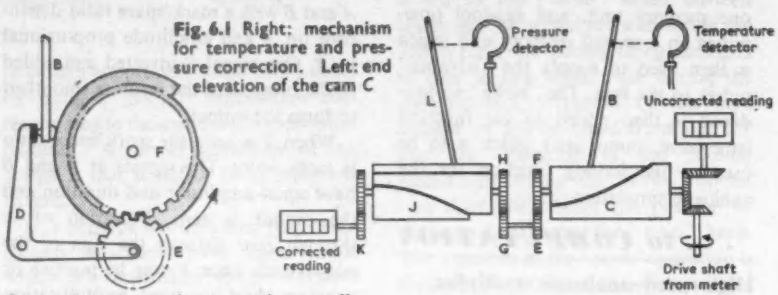


Fig. 6.1 Right: mechanism for temperature and pressure correction. Left: end elevation of the cam *C*

This device is intended for fitting to integrating meters giving a rotating-shaft output. It is based on the classical cam-type mechanical integrator which has been used on flowmeters for many years. Pressure and temperature correction may be provided, using two such mechanisms, or pressure only, using one mechanism. The system for giving both temperature and pressure connexion is shown in Fig. 6.1.

Temperature is detected by a Bourdon tube *A* which drives the arm *B* through a mechanical linkage. The lower end of *B* carries a follower which runs on the cylindrical cam *C*. While the follower is on the raised surface of *C*, gears *E* and *F* are in mesh. Consequently *G* and *H* are also in mesh, and the drive is taken to the second cylindrical cam, *J*. (The crank *D*, which transmits the motion from *B* to *E*, is omitted from the right-hand drawing in Fig. 6.1 for clarity.) Over a period, the ratio of the number of revolutions made by *J* to the revolutions of *C* depends on the position of *B* and the characteristic of the cam *C*. A similar mechanism provides the pressure correction, the gear *K* being dropped out of mesh by the action of the arm *L* and the cam *J*.

The required temperature and pressure correction laws can thus be built into the mechanism by the correct shaping of the cams *C* and *J*. If only pressure correction is required, only one cam is used. The equipment is designed to allow for temperature or pressure recorders to be mounted on it if required.

Flow controller for purge lines

In order to cope with the well-known problem of setting manual control valves on purge and bleed lines, where pressure fluctuations are encountered, a neat combination of Rotameter and flow regulator has been produced by the Brooks Instrument Co. It is intended to deal with flows up to 12 gal/min.

The principle of the device is to maintain a fixed differential across a needle valve, which is used to set the

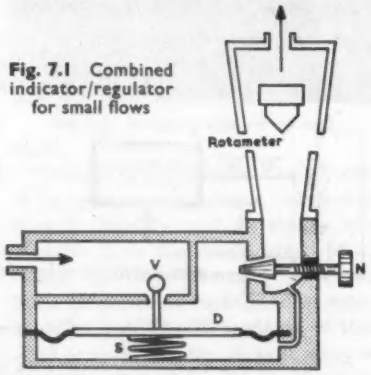


Fig. 7.1 Combined indicator/regulator for small flows

desired flow. The valve *N* (Fig. 7.1) is adjusted until the correct flow is registered by the Rotameter. Any change in the pressure drop across the seating of *N* moves the diaphragm *D* which controls the valve *V*. Thus a flow increase, causing an increase in the pressure drop across *N*, moves *D* downwards to restrict the orifice at *V* and restore the flow to the desired value.

The main topic discussed by our American correspondents this month is the ability of electric actuators to meet the demands of missile designers

Look at America

Electric actuators for missiles

Control of aerodynamic surfaces of today's missiles and aircraft is most commonly accomplished by hydraulic actuators, because of their high dynamic performance, relatively low weight, and small size. Clutch-type servo-mechanisms have been developed for these applications, but usually have had to be abandoned because of unsatisfactory reliability. Recently a number of gas-operated actuators has been developed for use in high temperature or radiation environments, where hydraulic systems are often found to be unreliable or completely inoperable. Seldom have electric servo-systems been used for the typical 2–10 horsepower actuator application, because of their inferiority to hydraulic systems with respect to size, weight, and dynamic performance. However, with the advent of solid-state control devices for electric energy, it would appear possible to develop a highly reliable electric servo-system for control-surface actuation. In an interesting paper presented at the recent Joint Automatic Control Conference, Newton and Rasche explore the theoretical feasibility of developing unconventional electrical devices to meet the performance requirements imposed by missile control surface applications (*1*).

In order to establish a theoretical basis for answering this question of feasibility, it is first shown that there is a single performance parameter that is most definitive in determining the suitability of an electric motor in a high-performance system. For a motor driving a load through conventional gearing, it is found (with a few judicious assumptions) that two basic relations must be fulfilled if the motor is to be capable of driving the load. First, the motor velocity (V_m) must be equal to or greater than that required by the load (V_l). Thus,

$$V_m > R_g V_l \qquad (1)$$

where R_g = gear ratio.

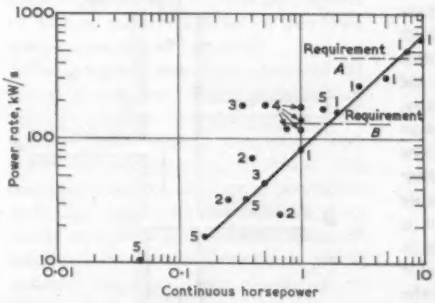
Second, the motor torque capability (T_m) must exceed the peak torque required by the load (T_l) after making allowance for the torque required to accelerate the motor itself. Therefore

$$T_m > J_m R_g a_l + (J_l a_l + T_l)/R_g \qquad (2)$$

where J_m = motor inertia, J_l = load inertia, T_l = load peak external torque requirement, a_l = load peak acceleration requirement.

On the basis of these two relations the motor size required to drive a specified load can be determined. In a previous paper by Newton (*2*) it is shown that in most typical control-surface applications, condition (2) above governs the motor size determination. From relation 2 an optimum gear-ratio can be determined by minimizing the right member with respect R_g. Then

$$(R_g)_{\text{optimum}} = \sqrt{\left(\frac{J_l a_l + T_l}{J_m a_l}\right)} \qquad (3)$$



Combining relations 2 and 3 yields the following interesting result:

$$\dot{P}_m = \frac{T^2}{J} > 4(J_l a_l + T_l)a_l \qquad (4)$$

Thus it is concluded that the torque-squared to inertia ratio (or power rate) of the motor under no-load conditions must be equal to or greater than four times the peak power rate of the load, if the motor is to be capable of driving the load.

The results of a study of the power rate capabilities of conventional electric motors

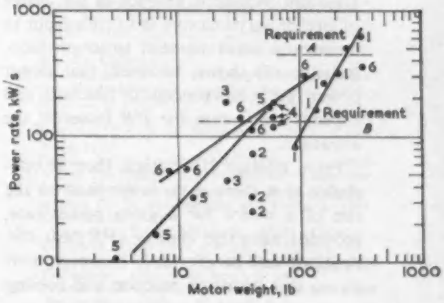
THIS MONTH

Electric actuators
Hydraulic logic
Computers for system design
Density measurement
J.A.C Conference
3-D displays

are shown in Figs. 1 and 2. Requirements *A* and *B* are believed to be representative actuator requirements for flap-controlled missiles. The obvious conclusion that is drawn from this study is that the electric

Fig. 1 Power rate v horsepower for five available motors. 1, G.E. kinematic series; 2, G.E. d.c. servo 5BC48AB; 3, G.E. d.c. servo 5BBY29YA; 4, G.E. d.c. 5BBY49YA; 5, Printed Motors d.c. servo. Nos. 1–4 inclusive plotted for 5 × rated current.

Fig. 2 Power rate v motor weight for six available motors. 1, G.E. kinematic series; 2, G.E. d.c. servo 5BC48AB; 3, G.E. d.c. servo 5BBY29YA; 4, G.E. d.c. servo 5BBY49YA; 5, Printed Motors d.c. servo; 6, Inland torque motor. Nos. 1–5 inclusive plotted for 5 × rated current, No. 6 for 2 × rated current.



motors alone (*not* including control circuitry and power source) for the hypothetical requirement *A* will weigh 15 times as much as a complete hydraulic system (including control circuitry and power source) for performing the same function.

Instead of rejecting electric motors for missile actuator applications, Newton and Rasche explore the theoretical limit on the power rate of such devices as a function of size. Moving conductor d.c. motors are

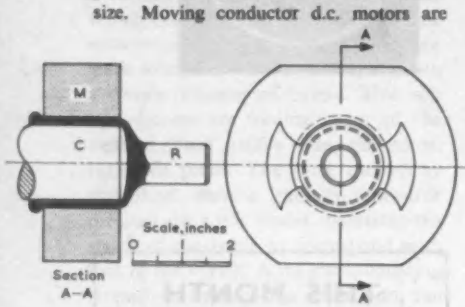


Fig. 3 Motor construction: *M*, an Alnico V magnet and pole-piece casting; *R*, moulded aluminium and glass-fibre rotor assembly; *C*, ferro-magnetic core.

considered and the following two questions are posed: (1) how should the motor be proportioned in order to produce the maximum power rate for a given size? (2) and what is the least size a motor may have for a given power rate?

These questions are answered for a shell-type motor configuration consisting of an armature in the form of a hollow shell which revolves around a stationary ferro-magnetic core. Field flux through opposing field poles is provided by an external magnetic circuit. An analysis in the paper shows that the power rate of the motor is proportional to the armature I^2R loss P_r. Specifically,

$$\dot{P}_m = (\alpha_p^2/\alpha_r\alpha_j)\,(\beta_f^2/\rho_m\rho_r)\,P_r \qquad (5)$$

where α_p is the fraction of the shell under the field poles, α_r is the ratio of the armature total resistance to the shell resistance, α_j is the ratio of armature total inertia to the shell inertia, β_f is the field flux density, ρ_r is the mean resistivity of the armature shell, and ρ_m is the mean density of the armature shell. On the basis that these parameters cannot be varied appreciably from one motor design to another, it is concluded that the motor power rate is substantially independent of the motor dimensions for a given power loss in the armature. Accepted practice in the design of electric servo-motors is to endeavour to maintain a small diameter to length ratio. Relation (5) shows, however, that motor power rate is independent of this ratio and depends only upon the I^2R losses in the armature.

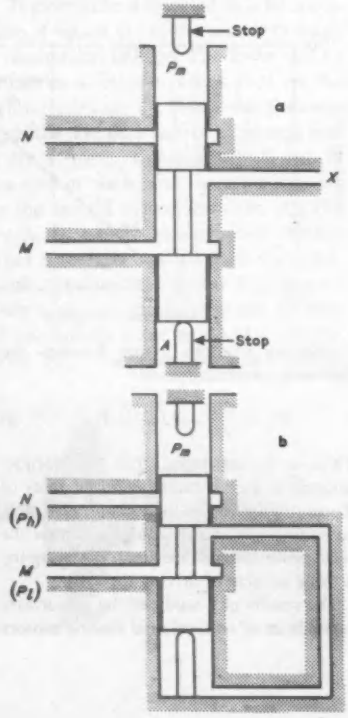
From relation (5) it might then be concluded that there is no lower limit to the size of a motor for a given power rate, provided adequate cooling (I^2R heat dissipation) can be provided. However, it is shown that armature reaction and cooling considerations place some very definite restraints on certain motor dimensions, namely the thickness and external surface area of the armature shell. Fortified with relation 5 and a knowledge of the necessary constraints on the dimensions of the armature shell, one is able to follow a simple procedure to design a motor for a particular requirement.

Newton and Rasche have designed a shell-type servo-motor in this manner capable of complying with requirement *A* (inertia of flap assembly = $0{\cdot}68 \times 10^{-3}$ kg m², maximum hinge moment = 102 newton-meters, maximum hinge acceleration = 1100 rad/s², maximum hinge rate = 20 rad/s, calculated power rate requirement = 452 kW/s). A sketch of the rotor and pole piece of the motor is shown in Fig. 3. The motor has the following characteristics: shell moment of inertia $J_m = 2{\cdot}18 \times 10^{-5}$ kg m², maximum motor torque $T_m = 3{\cdot}32$ newton-meters, power rate $P_m = 505$ kW/s. It is claimed that an overall system weight of three actuators (including cooling system and control circuitry) will be in the order of 50–60 pounds, which is of the same order of magnitude as for a comparable hydraulic system.

Hydraulic logic for computers

Over the past few years considerable work has been done on the development of fluid-operated (as opposed to electronically-operated) computer elements. Among these are the bi-stable jet devices developed both at the Diamond Ordnance Fuze Laboratory in the U.S. and in the U.S.S.R., and the diaphragm devices which have been developed mainly in the U.S.S.R. The newest group of devices of this type are hydraulic spool-type valves, used as signal generators rather than power modulators (*3*). Size of these components can be much smaller than ordinary spool valves, which allows them to be interconnected to form rather complicated logical networks.

Fig. 4 (a) Basic logic element; (b) bi-stable unit. P_h is an intermediate pressure between P_m and P_l.



Presence or absence of a pressure in the hydraulic components corresponds to presence or absence of a voltage in electronic computer components. In addition, the position of the valve spool can be used as an output signal. Figs. 4a and 4b show two basic elements. The device of Fig. 4a performs the Boolean operation

$$X = M\bar{A} + NA$$

while the device in Fig. 4b is a bi-stable element. The spool is stable in the position shown, but should a pressure pulse be applied at port *M* the spool will move to its upper position and remain there. It is readily possible to construct shift registers, exclusive OR networks, multi-vibrators and counters from the basic components of Fig. 4.

It still remains to be seen what practical applications exist for such components. Certainly response times are longer than those of electronic equipment (but are as good as or better than those of electrical relays) and operation with hydraulic fluid prevents their use at high temperatures. However, there may be a considerable area of application for these units as special switching or relay components for specific machinery requirements.

Computers for system design

In the design of controls for systems where the plant configuration has been previously established, the use of both analogue and digital computers can be of help in obtaining the optimum overall system (*4*). The digital computer is used to determine the plant's transfer characteristic. Once this has been accomplished, an analogue representation of the overall system including plant, controller, and compensating network, is used to arrive at an acceptable system from the standpoint of accuracy and dynamic behaviour.

As an example, the design of a positioning control system for a machine tool can be considered. Here the 'plant' refers to the equations of motion of the work-table, which must be determined before the design can be undertaken. One can attempt to determine these equations analytically, but frequently the results do not represent the physical system to a sufficient degree of accuracy. A more reliable technique, proposed by Callan in reference (*4*), involves the use of measured frequency and

phase response data. With these data at hand, fairly good guesses can be made as to the form of the transfer function. Once a guess is made, the digital computer is used to calculate the corresponding frequency and phase response, and to compare these with the empirical data. Changes are made in the parameters of the assumed transfer characteristic until the calculated and measured frequency response closely approximate to one another. If a suitably close approximation cannot be obtained, a different form must be assumed for the transfer characteristic, and the foregoing process repeated.

Once an analytical expression for the plant's dynamic behaviour has been obtained, the synthesis of an overall control system can begin. In this phase of the system design, an analogue computer becomes more convenient as a design tool since it allows frequent and rapid changes in the *kind* of control (proportional, 'bang-bang', proportional plus integral, etc.), as well as in the values of the important parameters. In addition, if a performance criterion is chosen such as the integral of error or integral of error squared, these quantities are easily calculated on the analogue machine.

The purpose of this discussion is to illustrate the usefulness of both types of computer in an overall system design. Without a digital machine, it would be a long, tedious task to find a transfer function that corresponds to measured frequency response data. At the same time, the analogue technique becomes more useful when stability and transient behaviour of the overall system are being considered.

Continuous density measurement

The need has long existed in the instrumentation and control field for a device which can accurately measure the density of a flowing liquid or gas. Most density measuring techniques in common use employ hydrometers or mechanical float devices. These devices are particularly difficult to use where continuous sampling is desired, because of their sensitivity to motion and other physical disturbances.

A new electromechanical device for measuring fluid density, called the 'Densitor', has been developed by Co-Engineering Co. (*5*). The Densitor, shown in Fig. 5, employs a measuring tube which is supported by a spring suspension and which is caused to vibrate (in a nutating motion) at its natural frequency by electromagnets. Two flow lines, connected to the source of material to be measured, keep the tube filled. The density of the fluid to be measured is then proportional to the resonant frequency of the spring mass suspension system. It is claimed that the Densitor is unaffected by flow velocity,

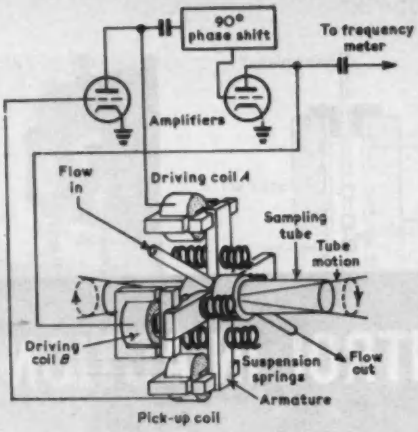


Fig. 5 'Densitor' sensing element

pressure, viscosity, or temperature and is insensitive to attitude. One particular model of the Densitor is capable of determining the density of fluids, mixtures and suspensions of solids in liquid, in continuous or batch sampling, with a maximum full-scale sensitivity of 0·1 specific gravity units. The temperature range is said to be $-60°F$ to $+200°F$, and the pressure range is -15 lbf/in² to $+200$ lbf/in².

Joint Automatic Control Conference

Recent advances in automatic control were discussed at the Second Joint Automatic Control Conference held June 28–30, 1961, at the University of Colorado, Boulder, Colorado. The J.A.C.C. was originally conceived to avoid duplicate, redundant, and overlapping control meetings. Five leading U.S. professional societies have provided active sponsorship and programming support—A.S.M.E., A.I.Ch.E., A.I.E.E., I.R.E., and I.S.A. These five sponsoring societies have agreed to hold no society meetings of their own solely on the subject of control.

The program this year contained 55 formal papers, two invited presentations, and two informal workshops. Among the general topics under discussion were theory of optimization, hydraulic and pneumatic control, economic parameters in process control, optimal switching, aerospace vehicle control, process dynamics, adaptive control systems, non-linear control systems, statistical design considerations, process and control non-linearities, and time series and process identification.

Three-dimensional displays

Two new three-dimensional display systems have been developed recently which show promise of wide-spread application in a number of fields, especially for air traffic control. The first of these systems is a stereoscopic display system demonstrated recently by Hughes Aircraft Company (*6*). With 'off the shelf' hardware the Hughes system provides a three-dimensional picture of the track of aircraft as they move through the sky. In the demonstration of the system, inputs to the display were supplied by Frescan, a three-dimensional radar developed by Hughes for the U.S. Army (see Fig. 6). A stereoscopic view is created using two Hughes Tonotrons mounted at right angles and directing their beams to a front-surface, half-silvered mirror. To the observer, the beams appear to coincide. Polaroid spectacles worn by the observer and Polaroid filters in front of each tube cause the information in one tube to be seen only by by the left eye. Correspondingly, information from the other tube is seen only by the right eye. The application of this three-dimensional display system to aircraft traffic control would appear to be a large step forward in an area where new developments are seriously needed.

The second of the new display systems is a glow tube containing a $3 \times 3 \times 5$ matrix of wires which generate three-dimensional images by rapidly shifting the localized glow from point-to-point (*7*). An experimental model of the tube, designed by Martin Ruderfer, president

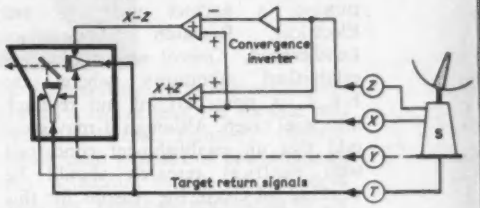


Fig. 6 Electronic three-dimensional display system

of Dimensions, Inc., has a gas environment of neon at 30mmHg. The wire matrix is so arranged that wires which cross one another do not touch. However, the wires are close enough to cause the gas to ionize and glow when the appropriate voltages are applied. A three-dimensional image is traced point-by-point by rapidly switching the voltages to selected pairs of wires. According to Mr Ruderfer, resolution comparable with that of cathode ray tubes can be achieved with proper design of the wire matrix.

Your American Correspondents

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CONTROL IN ACTION

Month by month—reports from the field

E.R.A.'s creep-of-steel laboratory

Temperature controls for creep research at Leatherhead

DURING A RECENT VISIT TO THE Electrical Research Association, Leatherhead, *Control* saw the newly established laboratory where the E.R.A. is now carrying out research into steel creep. Although it may seem odd that an establishment concerned with electrical research should be working on creep, the reasons for this are bound up with attempts to increase the efficiency of thermal power stations. Efficiency increases with steam temperature and pressure, and this means that the steels used in the boilers, pipe-work, and turbines should withstand high temperatures. The steel industry may develop a steel having promising high-temperature properties, but it is up to the E.R.A. to measure its creep and rupture properties in order that a power station using the new steel can be designed with the smallest safety factor for its twenty-year life.

The new laboratory is equipped with fifty high-sensitivity creep machines fitted with optical extensometers, fifty ten-specimen rupture machines, and fifty dual-purpose machines for creep measurements using dial gauges (Fig. 1) or for three-specimen multi-rupture testing (Fig. 2). All the machines were manufactured by Nash and Thompson. A fifteen-ton machine is installed for testing large steam-pipe specimens, and eleven thick-tube bursting rigs (Fig. 3) test tubes stressed internally by high-temperature steam.

Fig. 1 Multi-rupture testing machines with dial-gauge extensometers. The furnace temperatures are 450–750°C, and the operator is adjusting a furnace-temperature controller

Fig. 2 Attaching thermocouples to three specimens about to undergo a multi-rupture test

Extension measurement

A lever-arm system of applying tensile stress to specimens is used, the specimen being contained within an accurately temperature-controlled furnace. To measure creep on the high-sensitivity machines, an optical extensometer developed by the National Physical Laboratory is used. Basically, the extensometer comprises two limbs attached to the specimen; elongation of the specimen causes a rhomb to be rotated by the limbs, so causing a mirror attached to the rhomb to rotate; the mirror's angular displacement, which is proportional to specimen elongation, is measured by means of a telescope and scale.

Ten specimens joined in series by split couplings, can be tested in a furnace 50in long, in each of the ten-specimen rupture machines. As there are ten creep specimens in series a large extension occurs, and this is taken up automatically by a worm and wheel.

Specimen temperature control

Furnace temperatures are of the order of 650°C ±3degC. As a 0·4% change in voltage will produce a 3degC change of furnace temperature, compensation is arranged for mains voltage fluctuations. Compensation is also provided for changes in ambient temperature, although these have a less serious effect on furnace temperature.

Fig. 3 The control corridor for the thick-tube bursting rigs. The girl is adjusting a pressure-control valve and the assistant at the desk is measuring pressure-vessel temperature

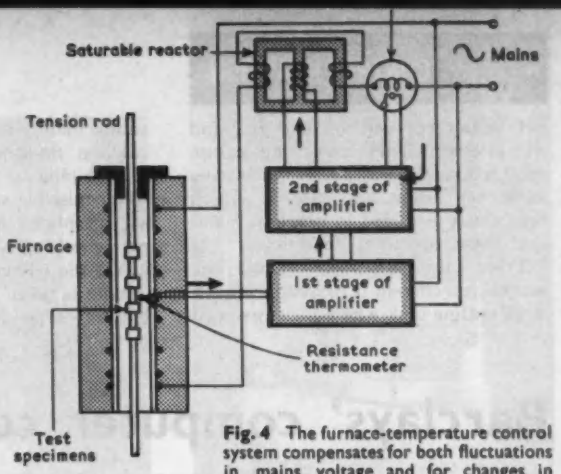

Fig. 4 The furnace-temperature control system compensates for both fluctuations in mains voltage and for changes in ambient temperature

The control equipment, which is by C.N.S. Instruments, is shown in Fig. 4. Assuming the ambient temperature to be constant, the basic problem is to hold the voltage across the furnace—and consequently the furnace temperature—constant. Fig. 4 shows that a fluctuation in mains voltage will—*via* the second stage of the amplifier—affect the characteristics of the saturable reactor, and so hold the voltage across the furnace constant. Changes in ambient temperature are sensed by a resistance thermometer resting tangentially against the furnace winding. If the ambient temperature changes, the furnace temperature will follow this change; the resistance thermometer is in one arm of a bridge, and the resulting unbalance signal is fed to the saturable reactor. The latter controls the furnace voltage in such a direction as to hold the temperature of the furnace at the required level.

If the controller failed, furnace temperature could rise rapidly and, in order to protect the equipment, a contact ammeter is fitted in series with the furnace winding. If the current rises greatly, a contact on the ammeter's pointer will eventually make with another contact, so placing a negative bias on the output valve in the controller and reducing the furnace current.

Fig. 5 Central desk at which measurements of temperature of all the specimens in the creep and rupture machines are recorded

Temperature measurement

Platinum/platinum–rhodium thermocouples attached to the specimens measure the test temperature, the short (20in) furnaces for rupture-testing three specimens in series, or for creep-testing larger specimens, having three thermocouples, and the 50in furnaces five thermocouples.

It will be appreciated that this large number of thermocouples could entail very many wires being returned to the central measuring room, and a great deal of platinum and many cold junctions would be needed. These problems have been overcome by the use of a system of switching close to the thermocouples.

All temperature measurements are made at the central desk shown in Fig. 5. Operating one switch at the desk actuates a switch near the furnace and switches all that furnace's thermocouples onto busbars of compensating wire. A second switch on the desk selects the busbar corresponding to the thermocouple required, and this is measured with a potentiometer. This system enables one cold junction only to be used from a set of busbars, and copper wire can be employed between the cold junction and the desk.

When setting up the furnaces, the thermocouples can be plugged into a recording system and measured at the furnace with a portable potentiometer.

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Effluent control at Texas Instruments

74,000gal/d under pH control

INSTRUMENT CONTROL TECHNIQUES ARE employed to a large extent at Texas Instruments' new semiconductor plant at Bedford, and their use of pH control of effluent, although fairly conventional, is of some interest. A considerable quantity of effluent is produced, this being made up of hydrofluoric, acetic and nitric acids of varying composition together with water-miscible solvents and, of course, a great deal of process water. The pH value can vary between 0·5 and 5·0. Up to 74,000gal/d, with peak flows of 7000gal/h, are automatically treated before being passed into the drains of the local authority.

Treatment of the effluent comprises a single-stage chemical treatment followed by settling of solids and final biological treatment. The effluent is held in two 3000gal balancing tanks before pumping under level control into a 1500gal treatment tank where lime slurry is added under pH control. It is understood that precipitation of solids takes place most effectively at

pH values between 7·5 and 8·0, and Pye industrial pH measuring equipment coupled to a Taylor pneumatic controller adjust the rate at which lime slurry is added in order to maintain these optimum conditions.

From the treatment tank, the neutralized effluent is passed through a large settling tank where the suspended solids, mainly in the form of insoluble calcium fluoride, are removed. The final biological treatment, where the water-miscible solvents are reduced to an acceptable level, precedes a final pH check. As the clarified liquor leaves the effluent plant, a continuous sample is taken and passed through a Pye flow-type electrode assembly, and a continuous recording of the final pH value is taken before the effluent is passed into the drains.

The treated effluent conforms to the local authority's requirements with fluorides below 30 parts/10^6, metals in suspension and solution 20 parts/10^6, suspended solids 20 parts/10^6 and a pH value between 6·0 and 9·0.

Barclays' computer centre

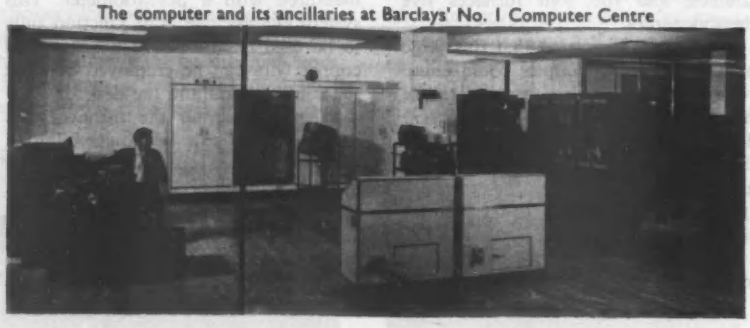
Automated book-keeping for 40,000 accounts at twelve branches

OPENED BY THE POSTMASTER GENERAL ON 4 July, Barclays' Bank No. 1 Computer Centre at Drummond Street, London N.W.1 is believed to provide the most advanced bank book-keeping system in the world. When the first computer—an Emidec 1100 of E.M.I. Electronics—is fully operative, it will handle the book-keeping of 40,000 accounts at twelve of Barclays' West End branches. During *Control's* visit to the Centre, however, work was being done for the Cavendish Square, and New Bond Street branches only.

The Emidec 1100 is, of course, a medium-sized, transistorized, machine having a magnetic-core immediate-access store of 1024 words, a 16,384-word magnetic drum, a parallel arithmetic unit, and a control unit in which the detailed operations to be performed for each instruction are derived from the lacing of a matrix of magnetic cores. Supporting the main computer are magnetic-tape units on which the main record for all accounts is stored. Photo-electric paper-tape readers, and high-speed paper-tape punches, both operating at 300 characters a second, provide input and output to the computer.

The twelve branches are connected with the Centre by teleprinter lines over which information on customers' entries is passed, so avoiding the movement of vouchers away from the branch. At each branch one or more accounting machines with paper-tape punching attachments are installed, and on these a journal is prepared analysing and proving all entries passing through the branch. As entries on customers' accounts are entered in this journal, details are punched into the paper tape as a by-product of this audit operation. Accounts are identified by account numbers printed on the cheques and paying-in books issued to customers.

The computer and its ancillaries at Barclays' No. 1 Computer Centre



After checking, the punched tapes are fed into the computer through a high-speed photo-electric tape reader. Magnetic tapes bearing a complete record of all customers' accounts to date, are mounted on 'read/write' machines, and this information is also fed into the computer. The computer combines these two sets of information—the old record and the day's entries—and records on a second magnetic tape an up-to-date account history. During this operation, new balances are obtained which are compared with limits, and interest, turnover, and other statistical calculations are made. A punched-paper tape containing the details required by the branch manager for the day-to-day control of his accounts is prepared, and this tape is teleprinted back to the branch where a record is printed.

Customers' statements are prepared on a diary or cycle basis, with a copy for retention by the bank as a ledger. Calls for statements are fed into the computer together with the up-to-date account records, and the statements are printed out in the branches ready for dispatch to customers.

Robotugs handle Rootes' stores

Driverless tractors used by motor-car firm

THE MAIN WAREHOUSE AT SMALL Heath, Birmingham, of Rootes Motors (Parts) Ltd, is now equipped with a system of electronically controlled Robotug driverless tractors.* Comprising two Robotugs and an extensive track, the system, which was supplied and installed by E.M.I. Electronics, is in operation as a pilot scheme and is to be extended to three other stores buildings eventually.

The Robotugs are used in 'goods inwards', handling material received by road vehicles from Rootes factories in special crates, and from other suppliers in either loose, crated or palletized form. Material received from the Rootes factories is transferred to trailers for towing by Robotugs to the

* 'Robotug installation at B.R. Wolverhampton', *Control*, 1960, *3* (Oct.), p. 123

Fig. 1 Four checking stations in the goods inwards department at Rootes Motors (Parts) Ltd, where Robotug automatic tractors are used

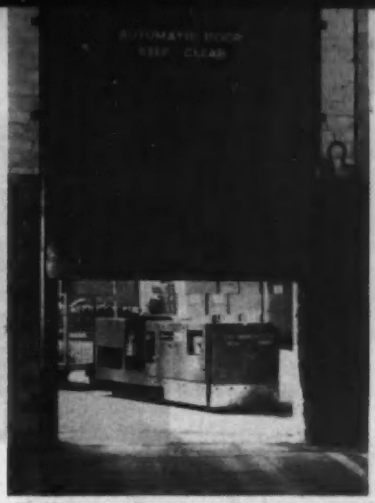


Fig. 2 Automatic tractor passes over contact point in track and actuates automatic door

lifts, which take them to stores areas on upper floors. Goods from other sources are loaded on to trailers which are towed to checking areas, after which, they are moved again by Robotugs to lifts for storing. On their return journey to the receiving area, the tractors take back empty trailers. An alternative by-pass route is sometimes used for transporting materials which do not require checking, directly to the lifts. This route is also used when several empty trailers need to be cleared quickly from the lifts.

An interesting feature of the system is the four automatically operated doors, which are actuated by the approaching Robotugs as they pass certain points. The track starts inside the building, goes out and comes back inside, goes out again to a covered way, and then returns into the building. The automatic doors exclude the draughts and cold air flows which would normally occur under these conditions.

Rootes use four different types of trailer for this parts-handling duty: a large platform trailer for such long loads as exhaust pipes; short-platform trailers for small pallets; drop-side mesh trailers for medium-sized components; and work-tin trailers for small components. Each trailer may carry 10–15 cwt, and a Robotug can tow one large platform trailer, two short-platform trailers or three component trailers. Although this is a reasonably large load, it can be handled by blocks of track of convenient length.

Adrema's production control system

Monitoring production data with Productograph

THE DATA-WRITING FIRM ADREMA LTD have acquired the British marketing and assembly rights for the Productograph system of Siemens-Halske, Germany. This system records production data from individual operating units in a production process, and many claims for production increases, better machine utilization etc, have been made for it. Adrema themselves have the Productograph system in operation in their machine shop, where it appears to be working well, although the installation has been in use for too short a time to provide worth-while comparative figures.

Basically, Productograph is supposed to provide backing services to the machine operator, rather than check upon his productive capacity. It is said that an employer knows already whether an operator is a good worker or not, and that the system would not be worth installing if the intention was merely to check on an operator's rate of output. Indeed, according to Adrema, 82% of production delays are not due to the man on the job, but to management's failure to provide materials, maintenance and so forth, and Productograph is expected to help overcome these failings.

The system obtains production information *via* transducers on, for example, individual machine tools or other machinery or processes. The resulting electrical signals are fed to the control centre in Fig. 1. The latter may deal with 20, 40, 60, 100 or 200 sources of information, although at Adrema eighteen machines only were being monitored.

The production situation is indicated on linear counters (Fig. 2, left) each of which consists of two film tapes situated behind a scale calibrated 0–30. (A decade plug-in arrangement enables each unit of the scale to represent ten, 100 or 1000 production units, as required.) A blue tape on the left of the panel shows actual production; a yellow tape on the right of the panel is preset to indicate the production required. When the required quantity of production is reached, the blue tape (actual production) meets the yellow tape (production required) and they overlap, the resulting green colour showing that the production requirement has been reached. This situation can then be automatically signalled to the operator, who may then transfer to other production. As can be seen in Fig. 2, each linear counter console covers twenty production lines so giving a co-ordinated view of a workshop or a section of it.

Adjacent to each linear counter are six-digit counters which indicate such extra data as machine-production time and idle time. On the main console (Fig. 1) there is a unit of six counters indicating integrated machine-operating times, and the total idle time with the reasons for this.

The main console incorporates various other facilities. There is an 'integrator for group control' which consists of a panel with squares which are illuminated to give an overall view of the operation of each production unit at any time. The heart of the system is a recorder which accepts signals from the transducers *via* two pens, one giving a linear diagram representing machine operating and standstill times, and the other indicating the reason for standstill and the production speed. The reason for a machine's ceasing to produce is sig-

Fig. 1 The Productograph production-control console at Adrema

Fig. 2 Linear counters (left) comprise yellow (actual production) and blue (production required) tapes which overlap to form green when production needs have been met. Digital counters (right) indicate both production and idle time

nalled to the recorder by the operator, who presses one of five buttons marked, say, 'materials awaited', 'inspection', 'break-down', 'maintenance' and 'setting'. This recorder operates at 0·5 mm/min, and is understood to simplify work study by indicating such factors as fatigue time. For more detailed analysis, a high-speed (30 mm/min) recorder may be used.

The machine operator's button panel is mounted at his station. When his work is interrupted, he presses the button keyed to the particular reason for the interruption, and this information is fed to the recorder and indicators at the console. A lamp on the button panel is illuminated when the transducers sense that production has ceased, and this warns the operator to press the appropriate button; when production starts again, the transducer senses this and releases the button automatically.

The Productograph system incorporates communications arrangements between the console operator, machine operators, stores etc., so that direct contact is possible between producer, control and administration. Furthermore, a tape recorder enables the operating instructions for, and reports from, say, the night staff, to be recorded. The complete installation can be switched on and off automatically by a timer.

Prospects

As already mentioned the system at Adrema has not been in operation long enough for conclusions to be drawn. However German experience—200 Productograph installations are in use in that country—does seem to suggest that the system has much to offer. For example, an 11% increase in production is said to be not unusual. The major problem would appear to be in the field of labour relations. However, Adrema claim that the system is in the interests of the worker for it enables him to earn larger production bonuses; he is no longer held up for material, for example, or wasting earning time while awaiting maintenance for his machine. It may well be argued that management has more to fear from Productograph than labour.

Turakina's hydraulic hatch covers

N.Z. cargo vessel's hatches auto-controlled

THE NEW ZEALAND SHIPPING Company's M.V. *Turakina* has hydraulically operated hatch covers on the weather deck, these giving faster cargo handling together with immediate protection for perishable cargoes in the event of bad weather. The covers are in two hinged halves, and a two-way lever-operated control valve for raising or lowering each half is enclosed in a cupboard attached to the side of each hatch. The four hatches are powered in pairs from two power packs in the ship's engine room.

Each motor and pump of the two power packs is double-ended and draws fluid from a common 50gal tank through filters. At one end of each unit is a large seven-cylinder pump with an output of 3·1gal/min, and at the opposite end is a smaller seven-cylinder pump with an output of 1·1gal/min. Under working conditions the output of both pumps is passed to the control valve. Depressing the control-valve lever passes pressure to the full area of a pair of cylinders (there being one pair to each hinged section of the hatch cover) so extending their rams to raise the cover; lifting the lever passes pressure to the annular ends of the cylinders thus lowering the covers. Independent control of the speed of raising and lowering is arranged for each movement.

Under non-working conditions, fluid pumped by the smaller pump blows off through a relief valve set to operate at 2800 lbf/in² and passes to drain *via* a restrictor valve. The back pressure created by this restrictor

Fig. 1 MacGregor–Lockheed hydraulically operated hatch cover in use.

valve is sufficient to move the spool of a hydraulically operated control valve, thus connecting the line leading from the pilot port of a pilot-operated relief valve to drain. The plunger of the relief valve then rises to allow the output of the larger pump to pass to drain.

As soon as the operation begins, the smaller pump ceases blowing off, thus relieving pressure on the spool of the hydraulically operated control valve. This is spring-returned and so no longer acts as pilot to the pilot-operated relief valve. The output of both pumps is thus available for operation again.

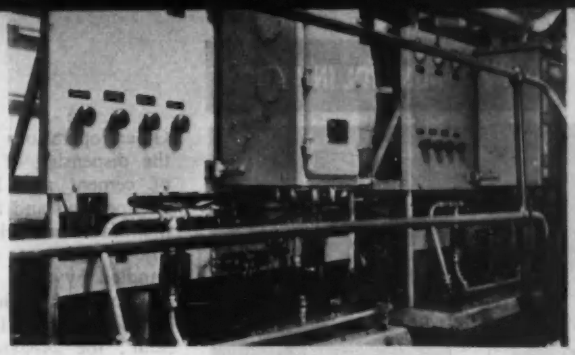


Fig. 2 These two power packs in *Turakina*'s engine room power the four hatch covers.

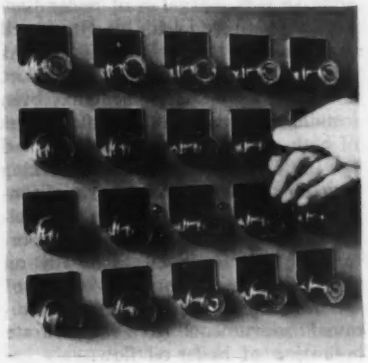
This form of unloading system keeps the system pressurized at 2800 lbf/in² under non-working conditions by the output of the smaller pump (at the same time allowing the larger pump to idle) so that instantaneous operation is available when required.

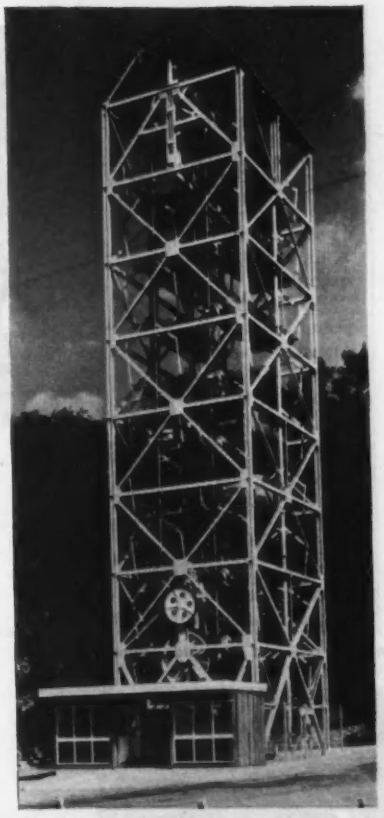
The system was developed by Lockheed Precision Products in collaboration with MacGregor & Co. (Cargo Handling) Ltd.

Car parking under auto-control

The 'Liftpark' which the Butterley Co. Ltd have introduced to the British market was demonstrated to *Control* recently. This is an automatic car-parking device, operating on the principle of the fun-fair's big wheel, car-carrying cabins replacing the usual gondolas. To park his car, the motorist drives into a cabin, alights, and enters the control kiosk. There he turns the key relating to the cabin he is using, from 'vacant' to 'park'. Cabin and car move up one side of the structure, an empty cabin taking the place at ground level of the cabin in use. To retrieve his vehicle, the motorist replaces the key in the lock relating to the particular cabin, turns it from 'park' to 'unpark' and his car is returned to ground level.

Control, which is based on Brookhirst Igranic's 'Bistat' static, contactless, logic system, is of fairly simple sequential type. Photocells at the entrance and exit to the Liftpark provide a signal to prevent the system operating if a vehicle should interrupt a light beam, and the system is further protected by electrically actuated traffic barriers by R. B. Pullin & Co.





Butterley's automatic car park and, left, the control panel.

Numerical control with Autopromt

Autopromt, a new and concise computer language having the form of simplified English, has been developed by I.B.M. This enables a three-dimensional shape to be described in terms of its surfaces, and a computer used to generate automatically the correct path to be followed by the machine tools making parts of that shape.

According to I.B.M., a complete helicopter-gearbox has been described in 180 one-line statements in Autopromt, and this information was then processed by an I.B.M. 7090 digital computer to generate more than 8000 tool-path instructions. These instructions, recorded on punched-paper tape for use by the machine tool, enabled the entire milling job to be completed in about one-quarter the machining time required to mill the same part by conventional methods.

The saving in overall time between drawing board and machine is claimed to be even more impressive. Apparently, conventional methods required three months planning-production time, but Autopromt allows any similar part to be in production in two weeks.

An Autopromt programmer works directly from the engineering drawing and describes the surfaces to be milled in normal machining terminology. This description of the part, handwritten on a coding sheet, is then punched into cards which are fed into the computer. The latter then generates tool-travel instructions for each surface to be machined. These tool paths are recorded on magnetic tape which can be converted to punched-paper tape for input to a machine-tool director.

R.A.E.'s controlled contour grinder

An electronically controlled contour grinding machine of high accuracy at R.A.E., Farnborough, is now producing templates used in the manufacture of aerofoil sections for aircraft wind-tunnel models. The models must be made to fine accuracy in order that they should have proportionally the same characteristics as the full-scale aircraft.

The grinding machine, which is by

Farnborough's tape-controlled grinder.

High Precision Equipment Ltd, is tape controlled by the Emicon system, the complete equipment being supplied by E.M.I. Electronics. The system has been designed to give an accuracy of ±0·0005in on a 30in long template.

Assembling equipment automatically

Kearney and Trecker–C.V.A. Ltd are to market the Transferline and Indexomatic assembly machines of Gilman Engineering and Manufacturing Co. (Janesville, Wisconsin, U.S.A.) in the U.K. The typical machines shown below are used by Allen-Bradley Co. (Wisconsin, U.S.A.) for assembling potentiometers, the arrangement consisting of a ten-station 6in Transferline (left in illustration) and a 24-station 6in Transferline. The use of cam-control of movements is said to enable these machines to perform many intricate loading operations. Other operations performed include the dispensing of accurate quantities of cement and lubricants, noiseless spin-peening and auto-unloading. The manufacturers claim that up to 27,648 different assemblies can be handled by these machines. The ten-station machine has a cycle time of 2s and produces 1800 components an hour; the 24-station machine has a 2·2s cycle time and produces 1636 components an hour.

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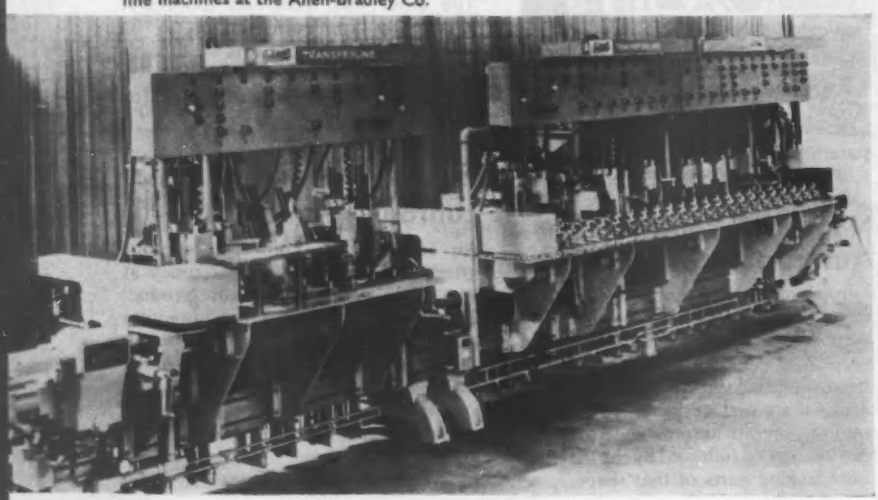

Tape-controlled drilling

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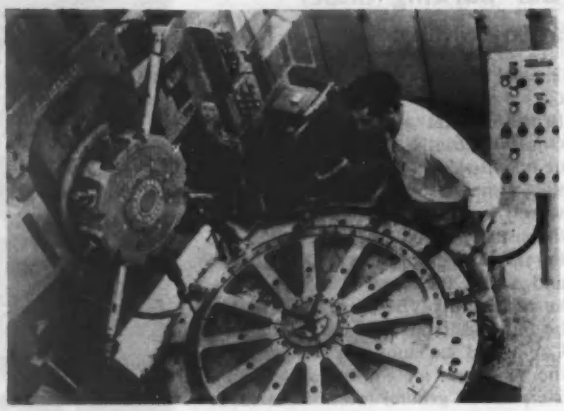
Tape-controlled Burgmaster machine with a 72in diameter workpiece on its 30in by 45in table.



The workpiece is 72in in diameter and is overhung on the 30in by 45in positioning table. Half the holes are machined in one set-up, and the remainder in a second set-up.

In the U.K., Ferranti's transistorized co-ordinate positioning system will be associated with the Burgmaster turret drill. Input information is provided either by co-ordinate dials or punched paper tape, the tape deck reading in a block of information of thirty lines simultaneously. The preset position from an arbitrary datum point is stored on decimal counters and a comparator decides the direction and motion to bring the counter indicators into line with the demand. The table then moves to the point of coincidence. Motion of the table is by means of hydraulic rams giving a setting time of 1s. At coincidence, the comparator produces a signal which changes the drive from rapid forward to slow reverse, causing the table to return through a small overshoot to coincidence again, when the drive is shut off and the clamps engaged. The counting system is checked using ternary logic, the drive being cut off if an error occurs. This check involves the use of Ferranti's moiré fringe system.

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Computers and E.C.M.A.

E.C.M.A., the European Computer Manufacturers' Association established in Geneva, has as its main purpose the furtherance of standards in data processing by establishing compatible systems and equipment, developing common systems languages and so forth. The new Association expects such standardization to enable data to be exchanged between systems, similar processes to be carried out on different machines, and the effort employed preparing programs to be much reduced.

Technical committees are already working on codes representing characters for input/output, common programming languages, and diagrammatic and symbolic representation of processes; a fourth committee will deal with character recognition.

E.C.M.A.'s President is C. G.

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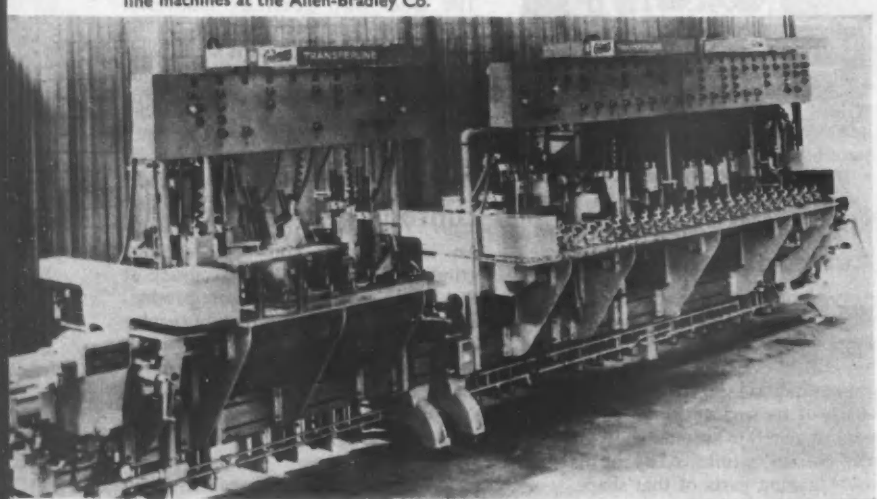

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The British Electrical and Allied Manufacturers' Association (Beama) have set up an Electronics Board to represent their members directly concerned with electronic engineering. The Board consists of Leon Bagrit (Elliott Bros)—Chairman, O. W. Humphreys (G.E.C.)—Vice-chairman, E. B. Banks (English Electric), W. S. Steel (A.E.I.), Sebastian de Ferranti (Ferranti), C. Metcalfe (E.M.I.), and the Chairman of Beama's Industrial Electronic Equipment Section, W. Gregson (Ferranti).

Computers and E.C.M.A.

E.C.M.A., the European Computer Manufacturers' Association established in Geneva, has as its main purpose the furtherance of standards in data processing by establishing compatible systems and equipment, developing common systems languages and so forth. The new Association expects such standardization to enable data to be exchanged between systems, similar processes to be carried out on different machines, and the effort employed preparing programs to be much reduced.

Technical committees are already working on codes representing characters for input/output, common programming languages, and diagrammatic and symbolic representation of processes; a fourth committee will deal with character recognition.

E.C.M.A.'s President is C. G.

S.T.C.'s a.t.c.-a.d.f. at L.A.P. The Ministry of Aviation's Experimental Unit at London Airport are conducting trials of a radio-direction finding system for the identification of radar target echoes. An automatic triangulation direction finder by Standard Telephones and Cables, is used in conjunction with the radar display (right). The d.f. equipment receives signals over land lines from remote stations as soon as an aircraft transmits, and displays these on the closed-circuit television monitor (left) to give an automatic 'fix'. As soon as a fix appears, a joystick control is operated to move a spot across the screen to mark the fix. This spot is duplicated on the radar display, and so identifies the particular echo relating to the transmitting aircraft.

Holland-Martin (I.C.T.), the Vice-President is P. Dreyfus (Compagnie des Machines Bull, France) and the Treasurer is M. R. Pedretti (I.B.M., France). The other firms in E.C.M.A. are I.T.T. Europe (Belgium—represented in the U.K. by S.T. & C.), S.E.A. (France), Siemens & Halske, Telefunken, and Zuse (Germany), Olivetti (Italy), N.V. Electrologica (Netherlands), Aktiebolaget Addo, and Facit Electronics (Sweden), and A.E.I., E.M.I., Elliott Bros, English Electric, Ferranti, and Leo Computers.

Smiths reorganize

Last year, subsidiaries of S. Smith & Sons (England) Ltd concerned with industrial equipment, were formed into Smiths Industrial Division. In early August this reorganization was taken a stage further on the formation of two further Divisions, one concerned with aviation and the other with shipping. The Aviation Division was formed from Smiths Aircraft Instruments, Kelvin & Hughes, and Waymouth Gauges & Instruments—companies producing aviation instruments and related equipment, and the Kelvin Hughes Division has been formed to carry on the marine business of the various Smiths companies.

Ralph Gordon-Smith is Chairman of all three Divisions; L. A. Morgan is General Manager of the Aviation Division; G. S. Sturrock is Deputy Chairman of the Kelvin Hughes Division with F. W. Bates as General Manager.

DATA PROCESSING

Solid-state Univac demonstrated

Remington Rand have installed a Univac 'Solid State 80' computer in their new offices in Holborn Viaduct, London, E.C.1, where it is handling internal accounting and statistical work. *Control* visited the new building, Remington House, last month for a demonstration of the Univac's ability to perform a complex electricity-billing operation.

As with all these business data-processing systems, Univac is expandable and there are many refinements available for the basic (£75,000) system. The Univac demonstrated, however, would cost around £140,000; one demonstrator felt that much the same job could be done with a £100,000 set-up, although the performance would, of course, be degraded to that extent—'it all depends on what the particular user wants'.

The system demonstrated consisted of a high-speed card reader which accepted billing information in punched-card form, and fed this information to the central processor—the computer. The output, printed bills from the East Midlands Electricity Board, is produced at 600 line/min by a high-speed printer. A fourth equipment, the read-punch unit, presents the same processed information on punched cards.

The demonstration showed the computer's ability to perform six operations simultaneously: (1) it calculated consumption from meter readings, integrating the readings if several tariffs applied, breaking down the overall consumption into tariff-blocks, calculating the charges per block and arriving at a total charge; (2) it compared the present consumption with that for the previous corresponding quarter; (3) it checked that year-to-year variations in consumption fell within ±20%; (4) it prepared figures for analytical purposes, i.e. by tariffs, number of rooms, trades etc; (5) printed bills at 600 lines of 130 characters/min; (6) up-dated consumer records.

The electricity-billing demonstration was quite impressive but much more so were the figures for costs. According to Mr F. de L.-Kennedy (Systems Adviser, Univac Computer Division) electricity billing by the existing method costs about 8s. per consumer per year; with Univac the figure would be about 3s. 4d. *and* the machine-cost would be paid off in one year.

GAS

Telemetry for grid

U.H.F. radio telemetry equipment by Pye Telecommunications in conjunction with instruments and controls by George Kent, will enable a large number of points at the major holder stations of the North Wales Gas grid to be monitored and controlled from a new operations room to be set up at Rhyl.

A total of 96 alarms, eight control functions and 28 measurements from ten holder stations, will be transmitted

NEWS BRIEFS

Production engineering summer school—*The inter-relation of work study, ergonomics, operational research and cybernetics and their application to production engineering*—will be held at the College of Aeronautics, Cranfield, from 29 August to 1 September. Details: The Institution of Production Engineers, 10 Chesterfield Street, London W.1; telephone, Grosvenor 5254–9.

Automatic wagon-handling controls by Brookhirst Igranic are to be installed at Thomas & Baldwin's new Spencer Works.

Bristol/Ferranti Bloodhound 2 semi-active homing ground-to-air weapon systems have been ordered by the Royal Swedish Air Board and by the Swiss Government. The Swiss order is expected to be worth £25–30m.

Pye-Ling Ltd, a new company concerned with vibration testing equipment, has been formed as a joint undertaking by Pye Ltd, and Ling-Temco Electronics (U.S.A. (The new company will be built up from the Vibration Division of the Pye-subsidiary W. Bryan Savage Ltd.

La Thermostatique S.A., the French subsidiary of the Rheostatic Co. (itself a member of the Elliott-Automation group), has become a wholly owned subsidiary of Elliott-Automation.

Swedish data-processing equipment. A.E.I.'s Electronic Apparatus Division have been appointed the sole agents in the U.K. and Commonwealth (except Canada) for the Facit Carousel memory, high-speed tape punch and high-speed reader of Facit Electronics AB, Sweden.

Midland Bank has ordered an English Electric KDP 10 computer system (£250,000) to service over 100,000 accounts.

Vactric Control Equipment Ltd are now at 30 Bouverie Street, London E.C.4; telephone, Ludgate Circus 7061.

Post Office have placed a £250,000 contract with Sovex Ltd for a mechanical parcel-sorting system.

to the required points over duplex radio links *via* a radio-repeater station at Great Orme's Head, Llandudno. These functions will be displayed and printed-out at regular intervals or on demand. Alarms reports will also be made during quiescent periods. The control settings can be adjusted in steps of 4% and a closed-loop control at each holder station will then maintain the flow at the set value.

The complete system (apart from existing pneumatic equipment) will operate from 24-volt batteries, trickle-charged from the mains supply. The radio equipment will comprise main and standby units with automatic change-over facilities, and the systems may be extended to include other stations within the grid network.

This telemetering system is understood to meet the specification issued recently by the Joint Radio Committee of the Nationalized Fuel and Power Industries, 1961. Copies of this *Basic specification for electronic telecontrol equipment* are available from G. D. Turton, Secretary, Joint Radio Committee of the Nationalized Fuel and Power Industries, c/o Central Electricity Generating Board, Bankside House, Sumner Street, London, S.E.1.

PETROLEUM

Pipeline for Basrah

A system for the remote control and data logging of oil-pipeline degassing stations, which is being supplied by Automatic Control Engineering to the Basrah Petroleum Co., incorporates telemetry and data-logging equipment by Standard Telephones and Cables. The degassing stations are at Rumaila, Qurainat, Shamiya and Junubia, the control centre being at Rumaila although this is being treated as a remote station like the others, Control and data transmissions are over pilot pairs in 20 lb/mile multi-conductor telephone cable. Controls and alarms will be transmitted at telephone-dialling speed, whereas data transmission is at telegraph speed—50 bauds.

The Rumaila control centre is to provide: telephonic communication between stations and Rumaila centre; an increase or decrease in pipeline flow, with simultaneous operation of all pumps; emergency shut-down; the logging of oil levels in tanks 1 and 2, main oil flow and pressure, and the temperatures at turbines 1, 2, 3 and 4—i.e. eight data displays for each station; and three alarm indications. All these data will be displayed continuously on digital indicators, and printed out by a Creed teleprinter either once an hour or on request. The equipment at each station will include an analogue-to-digital converter to which analogue information will be presented, in turn, in the form of a variable resistance for each parameter to be logged. The converter is basically a decade resistance bridge which balances automatically in two stages: a coarse (tens) and a fine (units) adjustment represent the percentage to be transmitted. Thus, twenty logical steps at most, will be required to balance the bridge. On their receipt at the control centre, the data are translated from the percentage form into practical units, such as barrel/day, before display. The accuracy of the system can be checked on receipt of a request signal from the control centre, by replacing the various parameter resistors with resistors of known value.

The equipment, which is now *en route* to the Middle East, was made by S.T. & C.'s Instrumentation and Control Division. The data system is fully transistorized and, for greater reliability, wrapped wiring techniques have been used instead of soldered joints. Most of the circuits are built up on small plug-in 'group' boards.

NOT WIRELESS-CONTROLLED

Vickers Vigilant wire-guided anti-tank missile at the moment of launch. The Vigilant is fired by a single operator using a pistol-grip control and sighting visually on his target. Thumb movements control the missile's flight, guidance signals being fed along a control wire unreeled from the rear of the weapon. Great accuracy is being obtained with this 200–1500yd range anti-tank weapon which incorporates its own autopilot gyro stabilizer. Velocity rather than acceleration control is used, in other words a single manual-control movement produces a proportional change in missile heading, returning the control to zero causing the missile to return to its original course but displaced laterally. Acceleration control, as is commonly used on other (less costly) weapons of this type, requires an operator of some skill.

B.C.A.C. HARROGATE CONFERENCE

Papers presented at the Conference, *Automation—men and money*, Harrogate, 27–30 June 1961:

ECONOMICS IN THE FIRM

Brech, E. F. L. (E. F. L. Brech & Partners Ltd): *Forecasting requirements for the firm.*

Risk, J. M. S. (Risk & Partners, Ltd): *Assessment of profitability, including net cash result of change and internal finances of firm. Means of raising finance within the firm.*

Stuchbery, A. L. (Chief Technical Engineer, Metal Box Co.): *Physical requirements of automation.*

Tait, B. D. (Cooper Bros. & Co.): *Relation of automation to optimum degree of variety.*

Jacobsen, A. A. (Inst. Prod. E.): *Case studies.*

WIDER ECONOMICS

Brown, J. A. C. (Sen. Res. Offr, Department of Applied Economics, University of Cambridge): *A review of the economic implications of automation, the effects on national economy, Government policy, and general labour implications.*

Williams, B. R. (Robert Ottley Professor of Economics, Manchester University): *Automation and the scale of industrial enterprise.*

Millson, P. C. (I.B.M. (U.K.) Ltd): *Internal comparisons on the speed of automation. Comparison of capital investment or h.p. per worker.*

Schumacher, E. F. (Economic Adviser, National Coal Board): *Economic forecasting for industry as a whole.*

Matthews, H. E. (Nat. Union of Gen. & Municipal Workers): *Case studies.*

SOCIAL ASPECTS IN THE FIRM

Crossman, E. R. F. W. (Institute of Experimental Psychology, Oxford University): *Operator selection and training for automation.*

Jones, J. L. (Secretary, Birmingham Branch, Transport & General Workers Union): *The effect of automation on wage structures and earnings incentives within the firm.*

MacDonald, J. M. (Chief Medical Officer, The Ford Motor Co.): *Social and psychological effects of automation in the modern working environment.*

Lupton, T. (Head of the Department of Industrial Administration, Birmingham College of Advanced Technology): *The effect of automation on organization and human relationships within the firm.*

WIDER SOCIAL ASPECTS

Clegg, Hugh (Fellow of Nuffield College, Oxford): *The effect of automation on employment, wages and working hours.*

Part, A. A. (Deputy-Secretary, Ministry of Education): *Education and automation.*

Carron, W. J. (President, Amalgamated Engineering Union): *The effect on industrial relations from the Trade Union angle, including their own problems of organization.*

Burns, T. (Senior Lecturer, Edinburgh University): *The effect on management structure and the management side of industrial relations.*

A full report of the Conference appears on page 68.

SCHUMACHER
cold douche from the coal board

PEOPLE IN CONTROL

by Staffman

'Old Moore plus a computer is still no better than Old Moore', said Sir **Walter Puckey** (I.C.T. etc.) at the recent Harrogate conference of the B.C.A.C. (reported by **G. M. E. Williams** of Northampton C.A.T. on page 68 of this issue). The N.C.B.'s Economic Adviser, **E. F. Schumacher**, was another Harrogate speaker adept with the cold douche. Schumacher thinks it 'statistical illiteracy' to confuse a forecast with a feasibility study, and warns against the misleading 'glitter of speed or the mysterious power of "feedback"'. But while he pooh-poohs automation in economic forecasting, Schumacher is all for the electronic computer when it comes to mathematical problems or production control. In other words, economics is not an exact science. Schumacher is quite right in this, as he is when he shrewdly observes that the user of a forecast is not helped by being given a range instead of a single figure—he usually just takes the mid-point and leaves it at that.

I see that **R. S. Phillips** has joined the Instrumentation Division of Evershed & Vignoles as Chief of Development dealing with electronic process control equipment. Phillips, who has been in the electronics industry for twenty years, went to Evershed's from Epsylon Industries where he was engaged on the development of process controls connected with the manufacture of textiles.

Allen West & Co., who have acquired the manufacturing interests of Digital Engineering, tell me that Dr **L. N. Bramley**, Digital's Managing Director, is to take up a full-time appointment in that capacity on 1 September. Bramley's colleague in the enterprise, **W. N. Jenkins**, also a Bisra man, is being retained as a consultant. Joining Digital's Board from Allen West are **G. H. Cann** (Chairman), **V. Laurence Breeze** (Deputy Managing Director), **J. Meares** (Secretary), **J. R. Stacey**, and **F. W. White.**

PHILLIPS
twenty years

BRAMLEY
full time

Well known to readers of *Control* (Letters to the Editor have poured in ever since his *The cybernetic company* appeared in June last year) **Stafford Beer** has left United Steel to become Managing Director of a new international firm of operational research consultants based in London. He was, of course, head of United Steel's Department of Operational Research and Cybernetics. His position at United Steel goes to **David Owen** who was assistant head of the Department.

At Sima's A.G.M. last month **A. W. Jones** of Fleming Radio was installed as President of the Association for the year 1961–62 by the retiring President, **G. C. Ottway** of W. O. Ottway & Co. The latter becomes a Vice-president, and other Honorary Officers elected are **R. E. Burnett** of Marconi Instruments (Vice-president and President-elect), **William Logan** of Avo (Hon. Sec.), and **G. S. Sturrock** of Kelvin & Hughes (Hon. Treasurer). The newly elected members to the Council are **J. E. C. Bailey** (Baird & Tatlock), **A. G. Peacock** (Mervyn Instruments), **L. B. Lambert** (Negretti & Zambra), **J. E. T. Haile** (Rank Precision Industries), **I. C. M. Worsfield** (W. H. Sanders Electronics), **H. Wyn Griffith** (Shirley Developments), and **A. Richardson** (Stanhope-Seta).

I was amused to learn that Jones, who founded Fleming Radio in 1945, claims that his philosophy in business is 'to have $n+1$ doors available for every n wolves'.

W. S. Elliott, who joined I.B.M. in 1956 to build up their research laboratories in this country, left them at the end of July. Elliott is, of course, well known for his contributions to the commercial digital computer. He joined the Research Laboratories of Elliott Brothers in 1948 and led the team that developed the Elliott 401 machine, the first packaged computer to be commercially produced in this country. He then went to Ferranti to lead the team which developed the Pegasus, another best-seller. At I.B.M.'s British laboratories, Elliott gathered around him one of the finest teams of computer engineers in Europe. Owing to commercial secrecy little is known publicly of what goes on at the laboratories, but the testimony of visitors and the contributions of its members at conferences, suggest to me work of an advanced nature and high standard.

R. B. Pullin & Co. have decided to widen their activities to include the whole field of electronics, electrics, and electromechanics, and I believe their appointment of Dr **Sidney Jones** as Technical Director to be a direct consequence of this policy. Jones was Director of Research Applications at the Central Electricity Board, being responsible for the development of automatic process controls. Whilst at T.R.E. (now R.R.E.), Malvern, he became interested in the automatic guidance of astronomical

JONES
infra-red guidance from R.A.E.

telescopes and received his Ph.D. for work with Professor **Arnold Tustin** (now at Imperial College) at Birmingham University on the development of a high-precision servo-drive for a photographic plate on the Isaac Newton telescope, Herstmonceux. He led the R.R.E. team concerned with the infra-red guidance of missiles, work leading to Firestreak. Jones was Superintendent of Defence Airborne Radar at Malvern from 1954–56, and headed R.A.E.'s Armament Department from 1956–59.

Last October *Control* carried an article *Controlling the manufacture of laminated plastics* by **Donald Lidgley**, **D. C. Lowe** and **D. A. Mackintosh**, all of Formica Ltd. Now I learn that Mackintosh has joined the Elliott company, E-A Automation Systems. He has been appointed Head of a new department specializing in automation in the paper and plastics industries.

AUTHORS IN CONTROL

G. M. E. Williams (*Automation—men and money*, page 68). See page 113, February 1961.

J. C. Farquhar (*Instrumentation and control in the fertilizer industry*, page 72) was educated in South Africa and graduated from the University of the Witwatersrand in 1934 with a B.Sc. in chemistry and physics, and honours in physical chemistry. Until the war, he worked at Modderfontein Dynamite Factory, then the largest explosives factory in the world. His duties included the chemical control of one of the first du Pont nitric acid plants to be erected outside the U.S.A., and the commissioning of the first Fauser ammonium nitrate plant to be built outside Italy. He was afterwards appointed Superintendent of the oleum, hydrochloric acid, and nitrocotton plants, and, during this period, was elected an Associate of the Royal Institute of Chemistry. After war service as a pilot in the Fleet Air Arm and Air Transport Auxiliary, he returned to industry in Britain as a technical adviser on fuels and lubricants with Shell. In 1949 he transferred to instrumentation and spent the next eight years with George Kent Ltd, largely on control application work. Since 1957, Farquhar has been with Fisons Fertilizers Ltd as Instrument Engineer and has been responsible for the introduction of instrumentation throughout the company's fertilizer works.

FARQUHAR

THOMPSON

P. M. Thompson (*Stepping into space*, page 76): following his Natural Science Tripos at Cambridge at the end of the war, Thompson spent 18 months with the Radio Physics Department at the University. He then worked for two years with Salford Electrical Instruments developing a military radio altimeter. In 1950 he went to Canada and joined the Radio Physics Laboratory of the Defence Research Board, and in 1953 he moved to the Board's Electronics Laboratory. There he worked on solid-state circuits until 1959, when he returned to England to join the Plessey Company's Research Laboratories at Roke Manor, Romsey.

P. F. Blackman (*Pole-zero approach to system analysis*, page 78). See page 126, November 1960

MEDLOCK

BISHOP

D. M. Bishop (*The second Imeko*, page 81) gained his M.A. (first-class honours) in mathematics and natural philosophy at Aberdeen University in 1942. He then joined R.E.M.E. and worked on radar, wireless and associated instruments until 1948, attaining the rank of Major while Secretary of the Inter-services Radio Measurements Committee. Bishop joined I.C.I. General Chemicals Division as an Instrument Manager in 1948, the Leathercloth Division in 1951, and the Central Instrument Laboratory in 1956, where he evaluated industrial instruments. Bishop joined I.C.I.'s Heavy Organic Chemicals Division as Instrument and Electrical Section Manager in February 1961.

R. S. Medlock (*Instruments at the Soviet exhibition*, page 83) joined George Kent Ltd as a research electro-chemist in 1935, on graduating from University College, London. In 1940 he was a control engineer and, six years later, Research Manager, becoming Research and Development Manager in 1948. He became Technical Director of George Kent Ltd in 1956, Technical and Home Sales Director in 1958, and, more recently, Engineering and Research Director. A Member of the I.E.E. and the Mech.E., and an A.R.I.C., Medlock was President of the Society of Instrument Technology during 1959–60. He specializes in process control, electrochemical measurements, and electronic measurement, and is *Control's* consultant on engineering and applications.

H. Graham Flegg (*Summer-school mathematics for control engineers*, page 86) was educated at Saint Andrews University where he graduated in mathematics in 1949. During the latter part of the war, he served in the Meterological Branch of the Royal Air Force. After returning to St Andrews to complete his degree, he rejoined the R.A.F. as an Education Officer in 1950. After holding a number of appointments, including being in charge of training in statistics, he was selected to attend the post-graduate two-year course at the College of Aeronautics where he specialized in the Electrical Engineering Department. He was awarded the Diploma of the College in 1959, obtaining a first. For a thesis on Boolean matrix algebra and its application to computer logic, he also obtained the Principal's Prize for the best mathematical thesis and the Woods of Colchester Prize in electrical engineering. Since July 1959 Squadron Leader Flegg has been a lecturer in mathematics at the Royal Air Force Technical College, Henlow. He has a book on switching algebra in the final stages of preparation and hopes that this will be followed by a book on Fourier, Laplace and z transforms.

G. L. Ashdown (*Electronic engineering components and materials*, page 89). See page 128, July 1961.

D. L. A. Barber (*High-speed analogue multiplier*, page 95) joined the Post Office Research Station in 1946 and obtained a B.Sc.(Eng.) degree at Northampton Polytechnic in 1953. He was appointed Scientific Officer at the National Physical Laboratory in 1954, and was concerned with circuit design applied to data-handling problems. Barber is now a Senior Scientific Officer with the Autonomics Division of the N.P.L. and is engaged on the development of new computing and instrumentation techniques in the field of adaptive control.

New for the user

A monthly review of instruments, components, equipment and machinery for automation

For further information, circle the appropriate number on the reply card facing page 130

TWIN POWER SUPPLY

general purpose, heavy duty

Intended mainly for computers, the Startronic model 124 is a chokeless power supply claimed to have a flat response from d.c. to 500 kc/s. Two independent outputs each provide 300V at 500mA; they may be series connected to give ±300V about earth, or paralleled to give 300V at 1A. Stability ratio (ΔV in/ΔV out) is better than 400:1. D.C. resistance is less than 0·1Ω, and a.c. impedance is less than 0·5Ω from 1 c/s to 500 kc/s. The unit, which requires a standard 50 c/s mains input, may be supplied either for mounting in a 19 in rack or in an instrument case.

Circle **No 522** on reply card

DATA PROCESSING SYSTEM

magnetic ledger cards

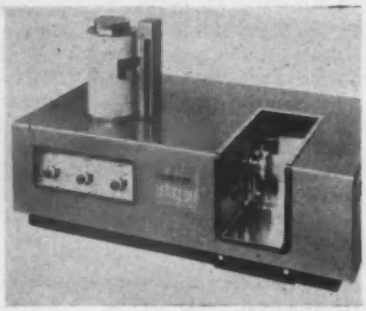
National Cash Register's 390 is designed for general purpose work in firms of all types. The complete system consists of a central processor, a console, and a variety of input, output, and memory units. Information may be fed in by direct keyboard entry, by punched tape, by punched cards, or by magnetically-encoded ledger cards, all of which methods may be used simultaneously. The magnetic ledger-card combines normal printed information and (on the back) a magnetic record. The magnetic record not only supplies accounting information, but can interrogate the central processor and modify the program instructions to suit the requirements of a particular account.

Circle **No 544** on reply card

SPECTROPHOTOMETER

two scanning-speeds

An improved model of the Perkin-Elmer Infracord is now available. The model 137 gives an automatic record of an infrared spectrum from 2·5 to 15μm. Standard time for a complete spectrum is 12min, but a two-speed drive allows fast-survey spectra to be run in 3min. A new slit system is claimed to give improved



Improved resolution

resolution, particularly at short wavelengths, and the slit program may also be set at a number of different levels.. The unit requires a 50 c/s power supply, at 210, 230, or 250V a.c.

Circle **No 541** on reply card

MOISTURE CONTROL UNIT

continuous indication

Honeywells Moist-O-Graph, for use with automatic electronic instruments, is intended for use in the paper, textile, food and other industries. It is claimed that moisture content in paper of over 40% can be controlled.

Moisture content is measured by detecting resistance changes as the product passes between two conductive surfaces. Five models give facilities from simple measurement to complex cascade control. The transmitter output is 0–10mA, and may be fed into any compatible indicating, recording or controlling instrument.

Circle **No 550** on reply card

AUTOMATIC ASSEMBLY MACHINE

straight-line flow

Available in the U.K. from Kearney and Trecker–C.A.V. is the Gilman (U.S.A.) Transferline, an automatic assembly machine with straight-line transfer motion. This allows the use of a single cam-shaft to actuate all transfer and locating motions, so ensuring positive interlocking and synchronization. Interchangeable standard station-movements may be mounted anywhere alongside the basic machine, and redesign and retooling of a station entails only engineering the tooling to be attached to the mounting blocks on the slide, and profiling a simple plate-type cam. All the various standard components (drive units, cam switch assemblies, etc.) may be purchased separately.

Circle **No 515** on reply card

DISK STORAGE UNIT

high-speed access

The I.B.M. 1301 disk storage unit holds up to 56 million characters. It uses comb-like access arms; data, recorded in a pattern of 250 concentric tracks on magnetic disks, is read and written by these arms. Data may be transferred between the store and the computer at a speed up to 75,000 characters/s when feeding an I.B.M. 1410 computer, or 90,000 characters/s, feeding an I.B.M 7000 series computer.

Circle **No 535** on reply card

PNEUMATIC ACTUATOR

horizontal or vertical operation

The T.A.L. Pneumatics Speedmaster is available in four sizes from ¼in to ¼in B.S.P. It will move loads of over 1 ton faster than 2 ft/s, but is claimed to halt so gently that there is no shock damage. The mark I is intended for the movement of a load between two predetermined and preset positions; the mark II, in addition to this, incorporates a feature for arresting load movement between the two preset positions.

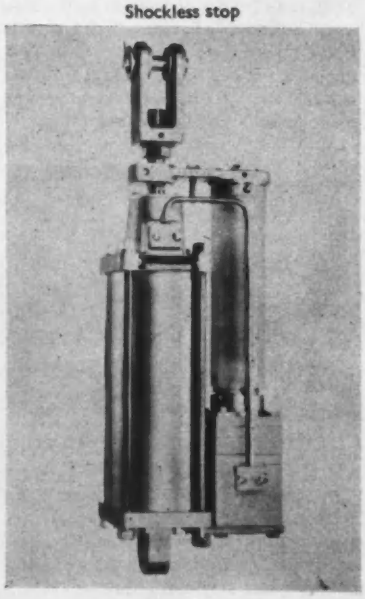
Circle **No 538** on reply card

PNEUMATIC POWER POSITIONER

loads up to 150 lbf

A small pneumatic actuator available from Hagan Controls will control unbalanced loads of up to 150 lbf. It is intended to drive valves, dampers, etc.

Shockless stop



With an air pressure of 100 lbf/in², under no load, full stroke takes 1·5s; frequency response with no load at 10% peak-to-peak input signal is 1·3c/s.

Circle **No 558** on reply card

MACHINE TOOLS

paper-tape programmed

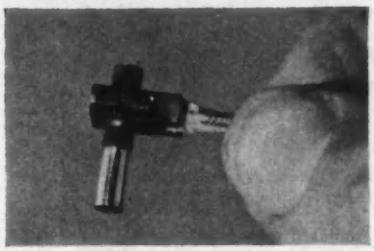
Four tape-controlled turret drilling machines by Burgmaster (U.S.A.) are available in the U.K. from Kearney and Trecker–C.A.V. The four models cover steel capacities up to 1¼in, and table travels up to 48 × 60in.

The tape reader is a motorized command unit, which controls table position in two axes, spindle selection, and sequence of operation. (Automatic depth control can be provided if required.) The program for a given 'machining' is written on a programming sheet, so designed that from it a typist can readily prepare the tape on a keyboard or other type of punch. Each of the *X* and *Y* dimensions occupies five digits: two whole numbers up to 99 and three decimal places. Information is read at the rate of one command block each second; when the block is read, the table is positioned and then table and saddle are clamped. The machine then carries out the commands punched for that block. Circle **No 517** on reply card

MINIATURE PRESSURE TRANSDUCER

small zero-drift

Developed by R.A.E., Farnborough, for wind-tunnel work, a miniature differential pressure transducer is available from



Short rise-time

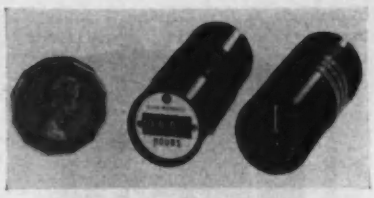
New Electronic Products in two pressure ranges: ±4 lbf/in² and ±10 lbf/in². Measuring only ¼ × ¼ × ¼ in, it operates on the variable capacity principle.

The transducer has a zero drift of 0·15%/deg C, and rise time is 15μs with a high carrier-frequency. The transducer is used in conjunction with an a.c. bridge with close-coupled ratio-arms, a carrier amplifier, and a phase-sensitive demodulator; the output, ±4·5V developed across an impedance of 5000Ω, may be applied to any suitable recorder or indicator. Circle **No 527** on reply card

ELAPSED-TIME INDICATOR

dial or digital indication

Made by Elgin (U.S.A.), and available in the U.K. from Aeromaritime, these elapsed-time indicators weigh approximately 1½ ounces. They have either dial



Small, rugged

or digital indication, and will record up to 1000h; certain other time ranges are also available. The units are cylindrical, diameter is 0·68in by 1·42in long (dial type) or 1·76in long (digital type). The dial type is claimed to be readable to within 0·1%. Supply required is 115 or 26V a.c., 400 c/s, and a 28V d.c. model is also available. Power consumption is 1W.

Environmental standards cover vibration up to 20*g*, 10–2000 c/s; temperature limits are −65 to +250°F (approx. −55 to +120°C). All shafts rotating faster than 5 rev/min have sapphire bearings, and the units are filled with an inert atmosphere to prevent moisture deterioration. The coils are epoxy-resin encapsulated.

Circle **No 531** on reply card

COLD-CATHODE THYRATRON

slow gas-clean-up

Cerberus (Switzerland) are manufacturing cold-cathode thyratrons with 3A ratings at 220, 380 and 500V a.c., and a 6A type for 380V a.c. Since there is no warm-up time, the tubes are operable immediately upon application of the anode voltage. Available in the U.K. from Walmore Electronics.

Circle **No 532** on reply card

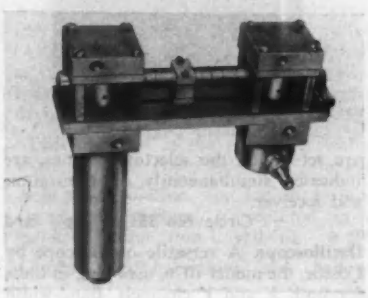
TOTALIZER RELAY

three pneumatic inputs

A relay by Hagan Controls consists of three receiving chambers containing sensitive diaphragms, and a fourth transmitting chamber containing a pilot valve and diaphragm. The four are mounted in opposing pairs, the pairs being interconnected by a balance beam carried on a thin sheet-steel fulcrum, the position of which is adjustable between wide limits. The output from the relay is the algebraic sum of the three input pressure signals.

In its standard form the unit can per-

Widely adjustable



form simple addition or subtraction, average two input signals, provide proportional control with or without integral action, provide derivative control action, or, when used in pairs, select the higher or lower of two input pressures. When fitted with a spring barrel, the relay can provide many other actions, including proportional control against a fixed set-point, with or without reset action. Circle **No 542** on reply card

QUICK LOOKS

Scintillation counting system. The Nuclear-Chicago (U.S.A.) model 701 is for research applications needing high sensitivity and efficiency in counting soft beta emitters such as carbon-14 or tritium. Although intended primarily for manually counting limited numbers of samples, it has provision for connecting an automatic sample-changer, a low-temperature changer, and a digital recorder. Circle **No 526** on reply card

Electronic weigher. The Fairbanks Morse model Q electronic weigher will weigh as little as 60 pounds, by 0·2 pound increments, or 800,000 pounds, by 200 pounds increments. The period for weigh-in and print-out is 3s.

Circle **No 539** on reply card

Bi-metal thermometer. Rototherm's 'Zero Re-set' thermometer can be re-calibrated by loosening an Allen key and rotating the thermometer stem. Adjustments up to 50% scale range are readily possible. Available with 2½, 4, and 7in dials, in all standard temperature ranges.

Circle **No 528** on reply card

Miniature relay. The B. & R. model B.14 weighs one ounce, and measures 1 × ⅔ × 1⅝in. It has one change-over contact, silver or silver cadmium oxide, the common contact being connected to the relay frame. Nominal operating power is 100mW, and operating time at this level is 3ms. Circle **No 529** on reply card

Time-delay valve. A time-delay Solenoid valve, the C2-XII, is available from British Arca. It has a ⅛in orifice, and will control pressures up to 170 lbf/in² for fuel oils between 750 and 950 Redwood No. 1. The delay action (5 to 7s) is effected by a resistance in series with the coil, coils being available for 110 or 230V a.c. operation.

Circle **No 530** on reply card

Ratio transformers. Two models by Gertsch (U.S.A.) are available from Wayne Kerr. The RT4 operates from 30–1000 c/s, and the RTS from 50–10,000 c/s. Over the lower frequency range, ratio accuracies of 0·001% are claimed, and 0·01% over the higher range. Ratios are selected by five decade-switches and a single-turn potentiometer.

Circle **No 545** on reply card

Cable tie. A self-locking cable tie by Insuloid is made from nylon to withstand temperatures from −80° to +150°C. They are claimed to be both lighter and stronger than their metal

Now for the user

counterparts. Three sizes cover cable diameters up to $\frac{5}{8}$in (L.K.1), $1\frac{1}{16}$in (LK.2) and 2in (LK.3) respectively.

Circle **No 546** on reply card

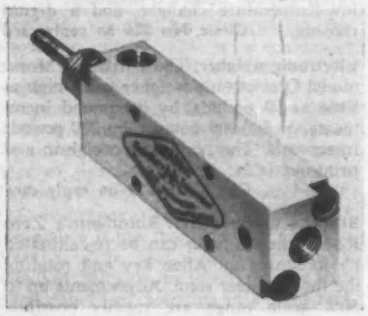
Relay contactor. An addition to their existing range, Keyswitch's relay operates on 230V and has 3 contacts rated at 30A. Screwed terminal connexions are used, and the unit may be supplied unhoused or enclosed in a transparent cover.

Circle **No 547** on reply card

Zener diode. A silicon reference diode by S.T.C. is capable of dissipating $7\frac{1}{2}$W when used with a suitable heat sink. It covers the range 6·8 to 50V, with a 5% tolerance. Maximum operating stud-temperature is 125°C.

Circle **No 548** on reply card

Air cylinders. A $\frac{1}{2}$in bore air cylinder, by Air Automation, has a rectangular section brass body and $\frac{1}{8}$in B.S.P. ports. It is available with stroke lengths from



$\frac{1}{2}$in to $1\frac{1}{2}$in, in single acting, double acting, and single-acting spring-return models. The piston rod is stainless steel, and rod and piston seals are Neoprene distributor type 'U' seals.

Circle **No 557** on reply card

Digital voltmeter. Solartron's LM 902.2R, for mounting on a standard 19in rack, is a flush panel version of their LM 902.2 bench model (See *Control*, March, 1961, p. 130.) Circle **No 559** on reply card

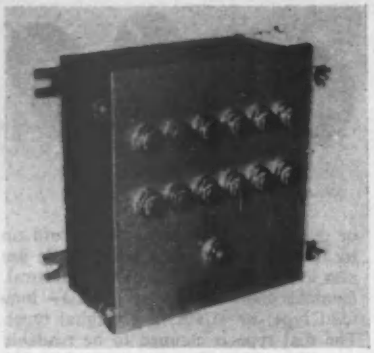
Accelerometer. The Endevco model 242 accelerometer is claimed to have a temperature linearity of ±5% from −320°F to +500°F (approx. −195 to +260°C). Dynamic range is 1000*g*, and frequency response (±5%) is 5 c/s to 7 kc/s (1000MΩ load) or 25 c/s to 7 kc/s (100MΩ load). Weight is one ounce.

Circle **No 525** on reply card

Rectifier assemblies. Available from Columbus Electronics (U.S.A.) are silicon rectifier assemblies with ratings up to 100,000V p.i.v., and d.c. current ratings from 10mA to 10A per half-wave assembly. Three basic series are produced: for convection or forced-air cooling; for operation in oil-filled containers; and cast in epoxy resin for severe environments.

Circle **No 537** on reply card

Alarm units. Made by Thomas Industrial Automation, these are available for one-, two-, or multi-point systems and any number may be added together to form a complete indicating system. Only one



cancellation button and audible alarm is required for any number of linked units.

Circle **No 536** on reply card

Decade resistance box. An inexpensive box by Levell Electronics uses Erie high-stability tropical insulated resistors. Four eleven-position switches give a resistance range of 10Ω to 111,100Ω in 10Ω intervals. Accuracy is ±1%, and temperature and voltage coefficients are respectively less than 0·05%/degC and less than 0·2μV/V d.c. applied.

Circle **No 549** on reply card

Electromagnetic clutches. Stationary-field clutches by Clark cover a torque range of 10 lbf in (model 1.75) to 90 lbf ft (model 8.00). Voltage required for any of the range is 24V d.c., but units can be provided with windings suitable for operation up to 90V d.c. The clutches are all of the dry plate type; it is claimed that no adjustment is required throughout life, and that 'take-up' for wear is automatic. Circle **No 540** on reply card

Digital telegraph. S. G. Brown's Tallygraph provides instantaneous transmission of three-digit numbers from a transmitter to any number of receivers over a multi-core cable. The numbers, which

are set up on the selector switches, are indicated simultaneously on transmitter and receiver.

Circle **No 551** on reply card

Oscilloscope. A versatile oscilloscope by Cossor, the model 1076, uses plug-in units for both *X* and *Y* channels. Band-width is d.c. to 60 Mc/s, at a sensitivity of 50 mV/cm, extending to above 100 Mc/s at reduced sensitivity. Delay facilities provide delays from 2μs to 10s, and the basic oscilloscope incorporates built-in 50 Mc/s and 500 Mc/s time-marker generators, the pulses of which are automatically locked to the trace.

Circle **No 543** on reply card

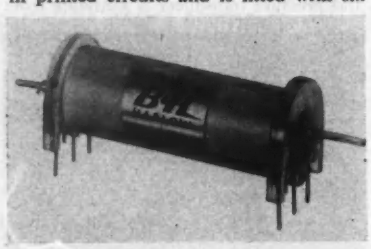
Continuous flow refractometer. Hilger and Watts's well known instrument has now been redesigned in three versions to suit different uses and environments. The M540 is a rack-mounted unit for use in clean atmospheres at normal pressure. The M541, for industrial use, is housed in a case designed to protect it against dirt, humidity, and oil vapour. Its associated electronics are in a separate unit for mounting in an equable environment. The M550 is a bench-mounted model intended for rapid batch-working in laboratories.

Circle **No 553** on reply card

Reversible timing motor. The series 46100 synchronous timing motor, by Haydon (U.S.A.) is claimed to have no slippage, to stop without coasting, and to be instantaneously reversible without mechanical aids. The motor operates on 115V, 50 or 60 c/s power supplies, and is available with 150 different output speeds from 300 rev/min to $\frac{1}{4}$ rev/h. Weight is 8 ounces.

Circle **No 554** on reply card

Relay. The type R.03 dry-reed relay, made by B. & R., is designed for use in printed circuits and is fitted with six



standard contact prongs. Coils are available with resistances up to 20kΩ, nominal power required being 0·06W. Contact resistance is 0·03Ω.

Circle **No 560** on reply card

Display oscilloscope. Airmec's model 279 oscilloscope has a 17in screen, and is intended for demonstration and instruction in schools, universities, etc. Sweep time is adjustable from 1s to 1ms. The *X*-amplifier has a sensitivity greater than 9cm/V peak-to-peak, and a band-width from d.c. to 8 kc/s (within 3dB). The *Y*-amplifier has four separate channels, and one, two, or four traces may be displayed simultaneously.

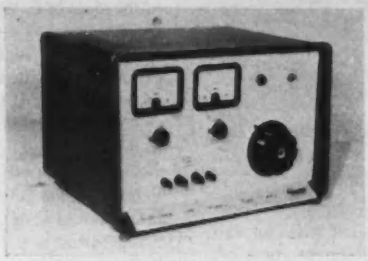
Circle **No 555** on reply card

Hygrometer alarm. An indicator/alarm by Shaw has a dial scaled as required either −120 to −20°C dewpoint, or in percentage relative humidity. A transistorized relay operates alarm or control contacts according to a pointer set by a thumb-screw under the dial. A feature of this instrument is that it will measure

moisture content of liquids such as kerosene. It is claimed that full scale indication is obtained for a concentration of 50 parts/10^6 of water in paraffin.
Circle **No 556** on reply card

Low pressure rams. Single- or double-acting versions of Chamberlain's BB ram are available with strokes ranging from ½in to 10ft. Designed to work on oil at a pressure of 2000 lbf/in², seven standard bore sizes are made, the largest having a thrust of 40 tons.
Circle **No 523** on reply card

Power supplies. Two transistorized supplies by Advance, the P.P.2 and the P.P.4, have outputs respectively 0–50V d.c. at up to 10A and 0–80V d.c. at up to 6A. A constant-voltage transformer helps to stabilize output voltage, and an electronic tripping-circuit is claimed to operate within 0·2ms of an overload occurring. A two-range voltmeter and a



four-range ammeter provide continuous monitoring. The current-selection switch on the ammeter automatically adjusts the overload circuit so that it operates at 150% f.s.d. Circle **No 552** on reply card

Microswitches. General Controls are now manufacturing a range of microswitches in the U.K. Four basic ranges are: pin actuator, side mounting; plunger actuator, sides or cover mounting; and a maintained-contact model, showing s.p.d.t. terminals and reset pin.
Circle **No 524** on reply card

Crystal calibrator. Marconi's TF 1374 covers the frequency range 100 kc/s to 1500 Mc/s with a stability claimed to be 1 part/10^8 per month. It provides check points in the form of head-phone zero-beats, occurring at switch-selected intervals of 10 Mc/s, 2 Mc/s, 500 kc/s, 100 kc/s, or 10 kc/s. Circle **No 521** on reply card

PUBLICATIONS RECEIVED

Valve engineering volume 2. *Edited by* **Richard S. Mandlekorn.** *Chapman & Hall Ltd. 1961. 167 pp. £3 7s.* ★ **566**

Static relays for electronic circuits. *Edited by* **Richard F. Blake.** *Reinhold/Chapman & Hall Ltd. 1961. 198 pp. £3 3s.* ★ **567**

Thrust bearings *by* **O. Gersdorfer.** *(A translation from 'Konstruktion', 1956, vol. 8, pp. 87–94 by R. G. Evan.) U.K.A.E.A. 1961. 22 pp.* ★ **568**

Adaptive control processes (A guided tour) *by* **Richard Bellman.** *Princeton University Press. 1961. 258 pp. £2 2s.* ★ **569**

The Computing and Data Processing Society of Canada—2nd Conference: June 6, 7, 1960. *University of Toronto Press. 1961. 365 pp. £2.* ★ **570**

Packaging directory. *The Tudor Press Ltd. 1961. 334 pp. £1 1s.* ★ **571**

The British Engineers' Handbook 1961—32nd edition. *The British Engineer's Assn. (Inc.) 1961. 608 pp. £1 1s.* ★ **572**

Encylopaedic dictionary of physics—volume 1. *Editor-in-chief* **J. Thewlis.** *Pergamon Press. 800 pp. £80 per set.* ★ **573**

Quality measurement in the chemical factory *by* **A. J. Clark** *and* **C. W. Munday.** *D.S.I.R. 1961. 22 pp. Free.* ★ **574**

The nuclear energy industry of the United Kingdom. *U.K.A.E.A. 1961. 68 pp.* ★ **575**

Automatic control and computer engineering *by* **V. V. Solodovnikov.** *Pergamon Press. 1961. 502 pp. £5.* ★ **576**

Introduction to transients *by* **D. K. McCleery.** *Chapman & Hall Ltd. 1961. 232 pp. £2 2s.* ★ **577**

Report of the Research Council for the year 1960. *D.S.I.R. H.M.S.O. 1961. 65 pp. 4s.* ★ **578**

'The absolute calibration of pick-ups on a drop-ball shock machine of the ballistic type' is the title of a pamphlet by R. R. Bouch of Endevco (U.S.A.). ★ **583**

Annual report. E.R.A.'s 1960 report gives details of its activities through the year. ★ **584**

Liquid level controller. The Resistron, by Thomas Industrial Automation, is the subject of a recent leaflet. ★ **585**

Gear de-burring. The Redin (U.S.A.) model 20 semi-automatic de-burring machine is described in a leaflet from Mortimer Machine Tool. ★ **586**

Electronic pre-heater. Radyne's model OCP 160, for resin-bonded and rubber products, is featured in a recent leaflet. ★ **587**

Stabilized d.c. supply. Claude Lyons's heavy duty supply, type PSS-32/50, is the subject of leaflet 6020/2. ★ **588**

High-temperature grease. Rocal's Molytherm grease is described in publication No. 17. ★ **589**

Moulding material. Turner Brothers' Durestos, consisting of blends of asbestos and thermosetting resins, is the subject of their 28-page booklet No. SA6. ★ **590**

Screened cubicles by Siemens are described in a leaflet from R. H. Cole. ★ **591**

'New things under the sun' is the title of Solartron's annual review. ★ **592**

Grain drying. Three leaflets from Negretti and Zambra describe temperature measurement systems for silos (APP/23) and storage bins (APP/24), and a control system for an electrically-heated high-temperature single-chamber drying installation (APP/25). ★ **593**

'Tube-in-Strip' is the title of a leaflet from Imperial Aluminium. ★ **594**

Acid gold solution, for use in printed circuit manufacture, is featured in a technical folder from Engelhard. ★ **595**

Gimbal, flexible joints and bellows assemblies are the subjects of an illustrated booklet from Avica. ★ **596**

Servo clamps made by Theta Instrument (U.S.A.) are listed in a technical bulletin. ★ **597**

'Prestincert' is the title of a Belling and Lee publication showing various types of 'pressed-in' mountings. ★ **598**

Precision wirewound resistors by Alma are listed on a selection chart under separate headings such as resistance, accuracy, minimum inductance, etc. ★ **599**

Export is the theme of a four-language booklet describing the activities of E.M.I. Electronics. ★ **600**

Dissolved-oxygen analyser. The Cambridge electrochemical analyser is described in their list 323/3. ★ **601**

Turbidity indicator and alarm. Radiovisors' photo-electric unit is the subject of their leaflet Ref. F561/T. ★ **602**

Gas analysis recorders for two and three constituents are listed in catalogue 163 from James Gordon. ★ **603**

'Terminalogy'. The first issue of a news sheet to be produced every other month by Sealectro. ★ **604**

Nucleonic equipment by Philips is detailed in an abridged illustrated catalogue (NR.3) from Research and Control Instruments. ★ **605**

Pneumatic servo-motors by James Gordon are described in catalogue No. 131. ★ **606**

Products and activities of the 600 Group are detailed in a leaflet from George Cohen. ★ **607**

Glass-fibre for plastics reinforcement. A 24-page illustrated booklet from Turner Brothers shows applications of their 'Duraglas' and 'Duramat'. ★ **608**

Sales and service overseas by Negretti and Zambra is the subject of publication S209. ★ **609**

Nitrogen and hydrogen plants by Incandescent Heat are featured in their bulletin No. V68. ★ **610**

★ Circle the relevant number on the reply card facing page 130 for further information

Book Reviews

Systems

Mathematics of engineering systems (linear and non-linear) 2nd edition, 1961 *by* **Derek F. Lawden.** *Methuen & Co. Ltd. 1961. 404 pp. 12s. 6d.*

To those familiar with the stiff-backed edition, this paper-back needs no recommendation at this price. Others may be reminded that here is an excellent account of the solution of linear differential equations by classical (*D*-operator) and Laplace transform methods. This occupies the first half of the book; an introductory chapter provides some of the basic mathematics required (function theory, complex variable). The second half of the book comprises a chapter on Fourier analysis, including a necessarily brief introduction to stochastic processes and noise, and a chapter on non-linear differential equations which is one of the best of its kind.

A particularly useful feature is the presence of numerous worked and unworked examples, and of solutions to all the latter. Though this is a textbook of mathematics and not of control engineering, many of the examples concern control systems, and Nyquist's stability criterion is proved in full. There is also a short treatment of sampling servo-mechanisms. The book can be strongly recommended to the student who wants to get to grips with the analysis of dynamical systems, and to the mature engineer who may have been perplexed by recent correspondence in *Control*.

N. REAM

Management

Engineering Management, Second edition *by* **Struan A. Robertson.** *Blackie & Son Ltd. 1960. 467 pp. £1 10s.*

This book was prepared as the basis for lectures to students at university and Higher National Certificate level, and its prime aim is to build a bridge between the techniques of engineering and the techniques of management, perhaps because they particularly occur in the problems of managing an engineering business.

The book is divided into three parts of which the first is concerned with management as an 'art', the art of getting people to take the initiative and also to co-operate. Motivation related to initiative is considered from a number of points of view, of which thirst for knowledge and the urge to crack difficult problems are placed high on the list, although the main reason why people work at all is conceded to stem from the need to earn a living. An important aim of co-operative work with others is claimed to be 'the integration of ideas' with the concept that the ultimate refinement of ideas coming from a number of personal sources will create a unity or wholeness which will be greater than the sum of the parts. I am not at all sure whether this inductive process really works out this way in practice—there is obviously some danger that committee compromising leads to the lowest common factor, so that the result is not even equal to the mere sum of the parts.

The second part of the book is on 'scientific management', or the methodological approach to the solution of organizational problems. Again this is based on the analysis of data with a view to pattern- and trend-finding, the inductive method. Why everyone assumes that science and the 'scientific method' are to be identified with induction goodness alone knows. The majority of important scientific work has been the result of a combination of genius, good guessing, and luck: but perhaps we need a new word for the pedestrian techniques called 'scientific management'.

The book goes forward with a formal description of the development of science, engineering, economics and the structure of industry, and culminates with a chapter on the development of scientific management and an account of the ideas of the principal pioneers in this subject. There is a particularly interesting analysis of the ideas of F. W. Taylor (1856-1915) with their insistence on the specialization of the individual to the detriment of craftsmanship and breadth of outlook. A great deal of the boredom nowadays experienced by the majority of workers in industry must be related to these 'scientific' ideas.

The third section of the book is on the practice of management in policy forming, organization, the factory, production, and with work-people and the customer. This part of the book may be useful in teaching the young at least some of the words used: but I am a little worried about this book because it gives the impression that management is a 'thing', whereas it is actually a property of human individuals. Experience of effective management indicates that essential properties are horse-sense, humour, and occasionally the ability to be quite ruthless, all human properties to which this book does not give much attention.

D. B. FOSTER

Computing

An introduction to electronic data processing for business *by* **Leonard W. Hein.** *D. Van Nostrand Company, Inc. Princeton, New Jersey, 1961. 320 pp + xiv with index. price £2 16s.*

This book, one of the Van Nostrand series in Business Administration and Economics, is by an Associate Professor of Business Administration at Los Angeles State College and has been developed, it is stated, from the author's experience in teaching e.d.p. to college students. The first six chapters rather sketchily introduce computers and their basic functions—their memories, inputs and outputs, punched-card layouts, the possibilities for calculation and decision, and program coding. The author has chosen to use an I.B.M. 650 magnetic-drum data-processing machine throughout the book as an illustrative model, and all examples are worked with this unit and its ancillary equipment in mind. Two simplified problems—processing of a weekly pay-roll and inventory control—are considered from conception to coding. Then follow chapters on file maintenance, merging and collating, sorting and report-writing on the computer. There is a final chapter on advanced programming concepts.

From a beginner's point of view the text is not always easy to follow. Steps or back-references are sometimes omitted, which makes for unnecessary difficulties. As an introduction to programming concepts the book is useful; it is well printed on good paper and the diagrams are particularly well placed in the text.

L. LANDON GOODMAN

Modern computing methods. *D.S.I.R. 1961. 170 pp. £1 1s.*

The fact that this book was originally produced from the lecture notes of a vacation school for electrical engineers, held at the Imperial College of Science and Technology, will give some idea of the style but only a misleading impression of the contents. It is in fact a very readable survey of modern numerical methods, and it has been extensively revised for the second edition.

Engineers with no time for detailed study may admire the combination of a brief statement of the problem with a series of notes on methods of solution. These notes are presented with examples and backed by the weight of the author's varied experience, though unfortunately lack of space often seems to limit them to an explanation of the 'best' method only. Systems of non-linear algebraic equations receive no mention, probably for the same reason, but this is the only obvious omission. There is an excellent bibliography, which is well supported from the text.

On the whole this slim volume is value for money, and an improvement in several respects over the original paper-back—which itself had a good reputation.

J. D. PEARSON